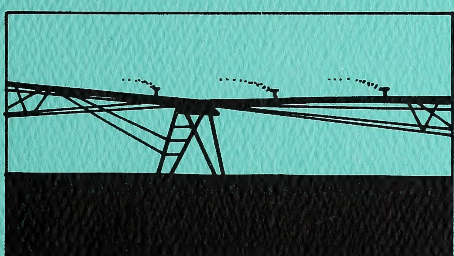
# IRRIGATION AND RESOURCE MANAGEMENT DIVISION



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APPLIED RESEARCH REPORT

IRRIGATION AND RESOURCE MANAGEMENT DIVISION

ALBERTA AGRICULTURE

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**PREFACE**

The Irrigation and Resource Management Division Annual Applied Research Report is a collection of progress and final research reports. The research is carried out by staff members of the division and private consultants retained under contract. Research projects vary from detailed tests to field surveys; from irrigation to conservation topics.

The reports are limited in length and summarize the highlights. The detailed data and information is available from the individual researchers. The reports have been grouped according to subject matter. The authors are responsible for the contents of the report.

## ACKNOWLEDGEMENTS

I would like to thank the many individuals and organizations who carried out the research and prepared the reports in this 1991-92 editionof the Applied Research Report of the Irrigation and Resource Management Division. I acknowledge the special effort by staff to plan and implement projects and bring them to a successful conclusion. On behalf of my staff I thank the farmers and irrigation districts and agricultural service boards for their cooperation.

I would like to thank also the administrative support staff and the drafting units for their assistance. In particular I would like to thank Hank VanderPluym and Diane Campion for compiling the 1991-92 division research report. I appreciate also the work by Tracey Munro in publishing the report.

Brian L. Colgan
Director
Irrigation & Resource Management Division

# IRRIGATION AND RESOURCE MANAGEMENT DIVISION

# APPLIED RESEARCH REPORT - 1991-92

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# IRRIGATION SUITABILITY OF SOLONETZIC SOIL ASSOCIATIONS IN EAST-CENTRAL ALBERTA (YEAR ONE-1991)

D.R. Bennett, T.M. Peters and P.D. Lund[1]

## INTRODUCTION

The objectives of this four-year study in the Berry Creek Basin are:

1) To determine the forage production capability of a number of different Chernozemic and Solonetzic soil associations in east-central Alberta under three levels of irrigation.

2) To assess changes in soil salinity and sodicity in these soils as a result of the three different levels of irrigation.

3) To evaluate the irrigation suitability of several different soil types in light of the various irrigation management regimes implemented.

This progress report contains a brief summary of results from monitoring conducted in 1991.

## METHODS

### Background

Four study sites in the Berry Creek Basin of east-central Alberta were selected for this project in the summer of 1990. Two of the study sites consist of predominantly Solonetzic soils (the Weich site near Hanna and the Blair site near Sheerness) and the other two sites (McNiven and Sunstrum) near Cessford have mainly Brown Chernozemic soils. The Solonetzic sites are situated adjacent to relatively large Ducks Unlimited reservoirs, whereas the two Chernozemic sites are located along Berry Creek.

Each study site consists of a rectangular field with dimensions of approximately 55 m wide by 340 m long. Four treatments, representing three target levels of irrigation - 200, 300 and 400 mm, and a dryland control - were replicated three times within each study site.

Two parallel transects situated 5 m from the side of each plot and starting 10.4 m from the lower boundary were used to characterize and sample ten soil profiles per plot (five per transect) in the fall of 1990. Each profile was sampled according to horizons, with representative samples taken from the A and B horizons and from the upper and lower C horizons to a depth of 1.2 m. Soil samples were analyzed for pH, electrical conductivity and soluble cations of the saturation paste extract and the sodium adsorption ratio (SAR) was calculated (Rhoades 1982).

### Cropping, Irrigation and Monitoring

Sites were prepared for cropping in the spring of 1991. Native prairie at each site was sprayed with glyphosate (Roundup) in early May of 1991 at a rate of 9 L $ha^{-1}$. Each site was subsequently broken from native prairie in mid-May using a cultivator and double disc, and Galt barley was seeded at a rate of 80 kg $ha^{-1}$ with a zero till truax drill. A solid set irrigation system was installed at each plot location and irrigation water was applied

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at a rate of 10 mm $h^{-1}$ in increments of 20, 30 and 40 mm on the 200, 300 and 400 mm treatments, respectively. Only six irrigation events were conducted at each site in 1991 due to the abnormally high levels of natural precipitation, resulting in total applications of 120, 180 and 240 mm to the 200, 300 and 400 mm treatments, respectively.

Crop yield was determined by sampling crops at the ten locations within each plot where soils were sampled. Soil samples were collected again in the fall of 1991 from the same ten locations within each plot.

## PRELIMINARY RESULTS AND DISCUSSION

### Site Characteristics

Soils within the Weich and Blair study sites are dominantly Solodized Solonetz, with at least 50 percent of the landscape consisting of Solonetzic soils. The associated Chernozemic soils at these two sites are mainly Solonetzic Dark Brown (Weich site) and Solonetzic Brown (Blair site). One Solonetzic order soil was detected at the McNiven site, with at least 60 percent of the soils classified as Orthic Brown Chernozemic, and the remainder as Solonetzic Brown Chernozemic. All of the soils investigated at the Sunstrum site are Orthic Brown Chernozemic, except for one Solonetzic Brown profile.

Replicate mean values for each soil chemical parameter and each soil horizon sampled in 1990 were analyzed statistically to assess the uniformity of treatments at each study site. Significant differences between treatments were not detected for any of the soil chemical parameters (data not shown), except for pH of the B horizon, indicating that initial soil characteristics were reasonably uniform at each study site prior to irrigation.

### Barley Yield and Water Applied

The significance of differences in total dry matter (TDM) and grain yield between treatments in 1991 (Fig. 1 and Table 1) indicates that a minimal response to irrigation was observed on the two Solonetzic study sites, with no significant differences in TDM or grain yield between treatments at the Blair site and only a significant increase in grain yield on the 200 mm treatment at the Weich site. Excessive amounts of natural precipitation in June, immediately following an irrigation event at these two sites, resulted in substantial surface ponding and runoff, with associated stunting and reduction in barley growth. Surface ponding was particularly evident on the 300 and 400 mm treatments at the Weich site where approximately 282 mm of precipitation was received, as compared to about 237 mm at the Blair site, 132 to 166 mm at the McNiven site and 150 to 176 mm at the Sunstrum site.

Significant differences in TDM and grain yield between the irrigation treatments and the dryland control were detected at both Chernozemic study sites, however, a significant increase in yield between the 200 mm treatment and the other irrigation treatments was only observed for TDM at the Sunstrum site. Lack of a yield response at the higher levels of irrigation at these sites may be attributable to deficiencies in natural soil fertility or to leaching by spring rains of the nitrogen mineralized following sod-breaking.

### Changes in Soil Salinity and Sodicity

Several statistically significant differences in soil salinity and sodicity were noted within the various treatments at each study site from

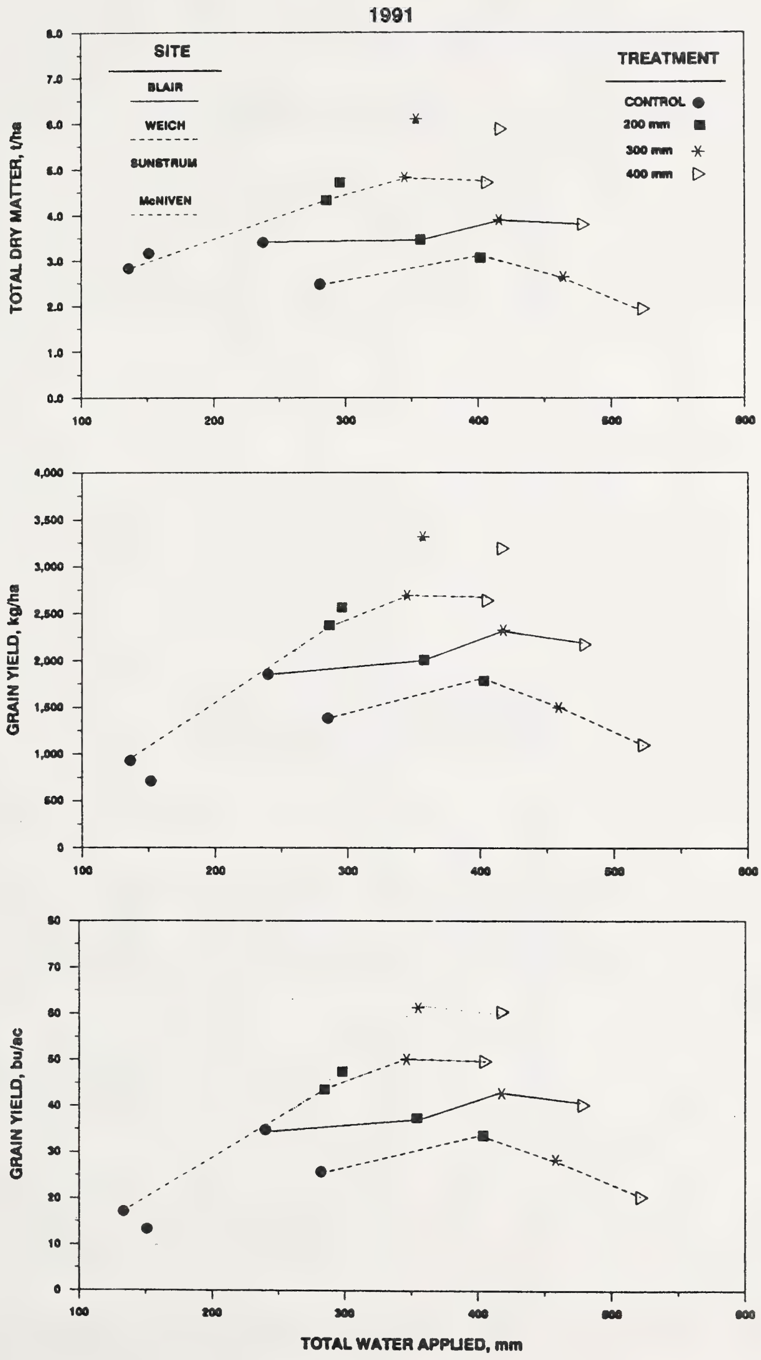


Figure 1. Mean barley yield on each treatment as related to the amount of natural precipitation and irrigation water applied in 1991.

Table 1. Comparison of mean barley yield from each treatment in 1991

| Site | Control | 200 mm | 300 mm | 400 mm | Probability |
|---|---|---|---|---|---|
| | | | Treatment[z] | | |
| | | | Total Dry Matter, t $ha^{-1}$ | | |
| Weich | 2.47bc | 3.11c | 2.64c | 1.91ab | $p < 0.05$ |
| Blair | 3.41a | 3.45a | 3.88a | 3.80a | $p < 0.01$ |
| McNiven | 2.79a | 4.33b | 4.81b | 4.74b | $p < 0.01$ |
| Sunstrum | 3.10a | 4.70b | 6.15c | 5.86c | $p < 0.01$ |
| | | | Grain Yield, kg $ha^{-1}$ (bu $ac^{-1}$) | | |
| Weich | 1366(25.4)a | 1813(33.7)b | 1488(27.7)ab | 1097(20.4)a | $p < 0.05$ |
| Blair | 1845(34.3)a | 1998(37.2)a | 2311(43.0)a | 2191(40.8)a | $p < 0.01$ |
| McNiven | 909(16.9)a | 2354(43.8)b | 2696(50.2)b | 2670(49.7)b | $p < 0.01$ |
| Sunstrum | 702(13.1)a | 2545(47.4)b | 3317(61.7)b | 3212(59.8)b | $p < 0.01$ |

[z] Values for the treatments at each site followed by the same letter are not significantly different at $p < 0.01$ or $p < 0.05$, as determined by a protected least significant difference test.

1990 to 1991 (Table 2). A significant decrease in soil salinity in the B horizon was detected in all treatments at the Weich and Blair sites. Leaching of salts from the B horizon may be attributable to the abnormally high amounts of natural precipitation received in 1991 in addition to the irrigation water applied.

Significant increases in salinity were evident in the A horizon of the 400 mm irrigation treatment at the the Weich site and in all irrigation treatments at the Blair site. Higher levels of sodicity were also observed in 1991 within the A horizon of soils in the 300 and 400 mm irrigation treatments at the Weich site and in all irrigation treatments at the Blair site. Increases in salinity and sodicity in the A horizon of irrigation treatments may reflect the new equilibrium being established in these soils because of the quality of irrigation water. Irrigation water EC values at the Weich site ranged from about 0.14 to 0.27 dS $m^{-1}$, with SAR values from 1.5 to 2.6. Irrigation water at the Blair site had EC values from 0.60 to 0.74 dS $m^{-1}$ and SAR values of 3.8 to 4.2.

Increases in soil salinity and sodicity in the A horizon of soils in all irrigation treatments at the McNiven and Sunstrum sites were also noted in 1991. Berry Creek water, used for irrigating these sites, had EC values ranging from about 0.45 to 0.67 dS $m^{-1}$ and SAR values of 1.7 to 2.7. A significant increase in salinity was also observed in several horizons within the dryland control treatment at these sites. Additional monitoring is required to confirm the changes detected in 1991.

Table 2. Comparison of soil salinity and sodicity within each treatment at the four study sites from 1990 to 1991

| | | | Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Control | | 200 mm | | 300 mm | | 400 mm | |
| Site | Parameter | Horizon | 1990 | 1991 | 1990 | 1991 | 1990 | 1991 | 1990 | 1991 |
| Weich | ECe, dS $m^{-1}$ | A | 0.68 | 0.75 | 0.64 | 0.68 | 0.65 | 0.76 | 0.65 | 0.84* |
| | | B | 2.66 | 1.71** | 2.88 | 1.87** | 2.54 | 1.75** | 2.87 | 2.28** |
| | | C1 | 5.54 | 4.84 | 5.57 | 5.00 | 6.45 | 6.02 | 6.25 | 5.97 |
| | | C2 | 7.91 | 7.27* | 6.61 | 6.56 | 7.68 | 6.55** | 8.11 | 7.47* |
| | SAR | A | 4.05 | 4.26 | 3.89 | 4.54 | 3.45 | 4.64** | 5.70 | 6.77* |
| | | B | 9.58 | 9.14 | 11.05 | 10.23 | 9.96 | 10.42 | 13.03 | 13.14 |
| | | C1 | 9.98 | 11.15* | 11.54 | 11.51 | 10.82 | 11.33 | 13.06 | 13.56 |
| | | C2 | 13.25 | 12.45 | 12.60 | 12.36 | 12.40 | 11.90 | 13.13 | 13.16 |
| Blair | ECe, dS $m^{-1}$ | A | 0.59 | 0.52 | 0.48 | 0.82** | 0.49 | 0.88** | 0.39 | 0.78** |
| | | B | 4.39 | 2.82** | 3.49 | 2.53* | 2.41 | 1.69** | 3.90 | 2.22** |
| | | C1 | 6.96 | 6.82 | 6.78 | 6.65 | 5.48 | 4.59 | 7.80 | 6.98 |
| | | C2 | 7.48 | 7.43 | 7.64 | 7.60 | 7.24 | 6.32 | 10.04 | 8.49 |
| | SAR | A | 3.90 | 3.47 | 3.59 | 5.07** | 2.78 | 4.98** | 3.33 | 5.70** |
| | | B | 12.67 | 12.36 | 12.86 | 12.27 | 9.90 | 9.22 | 12.77 | 13.51 |
| | | C1 | 11.55 | 12.40 | 14.23 | 13.56 | 10.93 | 10.68 | 13.96 | 14.85 |
| | | C2 | 13.01 | 13.11 | 15.33 | 15.81 | 12.63 | 13.18 | 16.36 | 15.57 |
| McNiven | ECe, dS $m^{-1}$ | A | 0.27 | 0.45** | 0.30 | 0.74** | 0.27 | 0.76** | 0.22 | 0.88** |
| | | B | 0.26 | 0.34** | 0.30 | 0.38* | 0.35 | 0.42 | 0.20 | 0.43** |
| | | C1 | 0.63 | 0.72 | 0.61 | 0.66 | 0.60 | 0.56 | 0.39 | 0.58** |
| | | C2 | 1.09 | 0.89 | 1.95 | 1.79 | 1.81 | 1.25 | 1.13 | 0.96 |
| | SAR | A | 0.31 | 0.32 | 0.25 | 0.95** | 0.32 | 1.28** | 0.30 | 1.54** |
| | | B | 0.53 | 0.74** | 0.58 | 0.66 | 0.91 | 0.86 | 0.46 | 0.55* |
| | | C1 | 1.36 | 1.48 | 1.85 | 1.88 | 1.73 | 1.53 | 1.14 | 1.13 |
| | | C2 | 1.93 | 2.00 | 2.53 | 2.44 | 1.99 | 2.34* | 1.93 | 2.10 |
| Sunstrum | ECe, dS $m^{-1}$ | A | 0.28 | 0.64** | 0.25 | 0.59** | 0.28 | 0.72** | 0.27 | 0.77** |
| | | B | 0.41 | 0.45 | 0.60 | 0.63 | 0.39 | 0.51 | 0.31 | 0.56** |
| | | C1 | 0.60 | 0.81** | 0.66 | 1.19** | 0.59 | 0.87* | 0.62 | 0.81** |
| | | C2 | 0.99 | 1.46** | 1.34 | 1.66* | 0.92 | 1.50** | 1.07 | 1.04 |
| | SAR | A | 0.25 | 0.25 | 0.33 | 0.63** | 0.29 | 0.96** | 0.32 | 1.14** |
| | | B | 0.54 | 0.58 | 0.70 | 0.85 | 0.48 | 0.54 | 0.51 | 0.50 |
| | | C1 | 1.51 | 1.52 | 1.79 | 1.91 | 1.19 | 1.28 | 1.22 | 1.14 |
| | | C2 | 3.01 | 2.80 | 4.15 | 2.86 | 2.23 | 2.11 | 2.21 | 2.33 |

Based on a paired t-test, where n = 30 and differences between years are significant at $p < 0.05$ (*) or $p < 0.01$ (**).

## ACKNOWLEDGEMENTS

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# BARLEY YIELD AND SALT REDISTRIBUTION IN IRRIGATED SOILS WITH DIFFERENT DEPTHS TO SALINE-SODIC SUBSOIL

D.R. Bennett, P.D. Lund and T.M. Peters[1]

## INTRODUCTION

The objective of this two-year study was to monitor barley yield, moisture use and salt redistribution within irrigated soils characterized by different depths to moderately fine-textured, saline-sodic, glacial till subsoil.

## METHODS

Detailed methodology and initial soil salinity and sodicity levels for each treatment have been reported previously (Alberta Agriculture 1989). Treatments consisted of 0, 0.25, 0.5, 0.75, 1.0 and 1.4 m of clay loam to clay, nonsaline lacustrine soil added to 1.5 m long by 0.38 m (ID) polyvinylchloride lysimeters containing complementary depths of saline-sodic, glacial till subsoil of similar texture. Lysimeters were cropped to barley in 1988 and 1989 and irrigation water was applied in increments of 100 mm when the tension exceeded 50 kPa in tensiometers installed at a depth of 0.5 m.

## RESULTS AND DISCUSSION

<u>Barley Yield and Water Use</u>

A positive, linear relationship was observed for each of the barley yield parameters and the total amount of water used by the crop in 1988 and 1989 (Fig. 1). Mean consumptive water use in each treatment during the two-

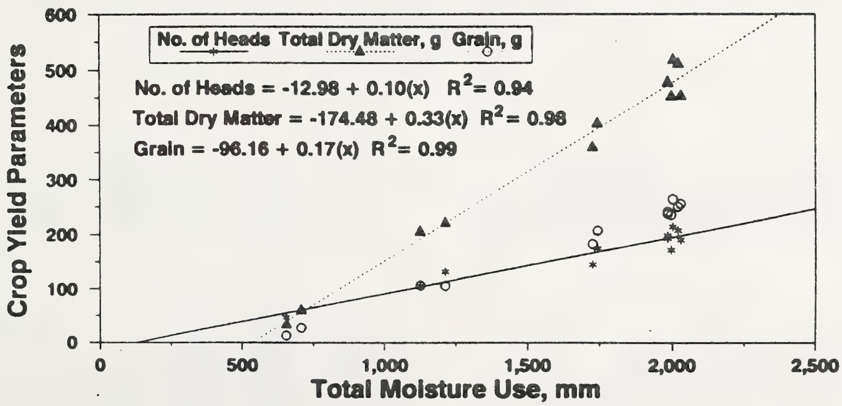


Figure 1. Cumulative crop yield and total moisture use in 1988 and 1989.

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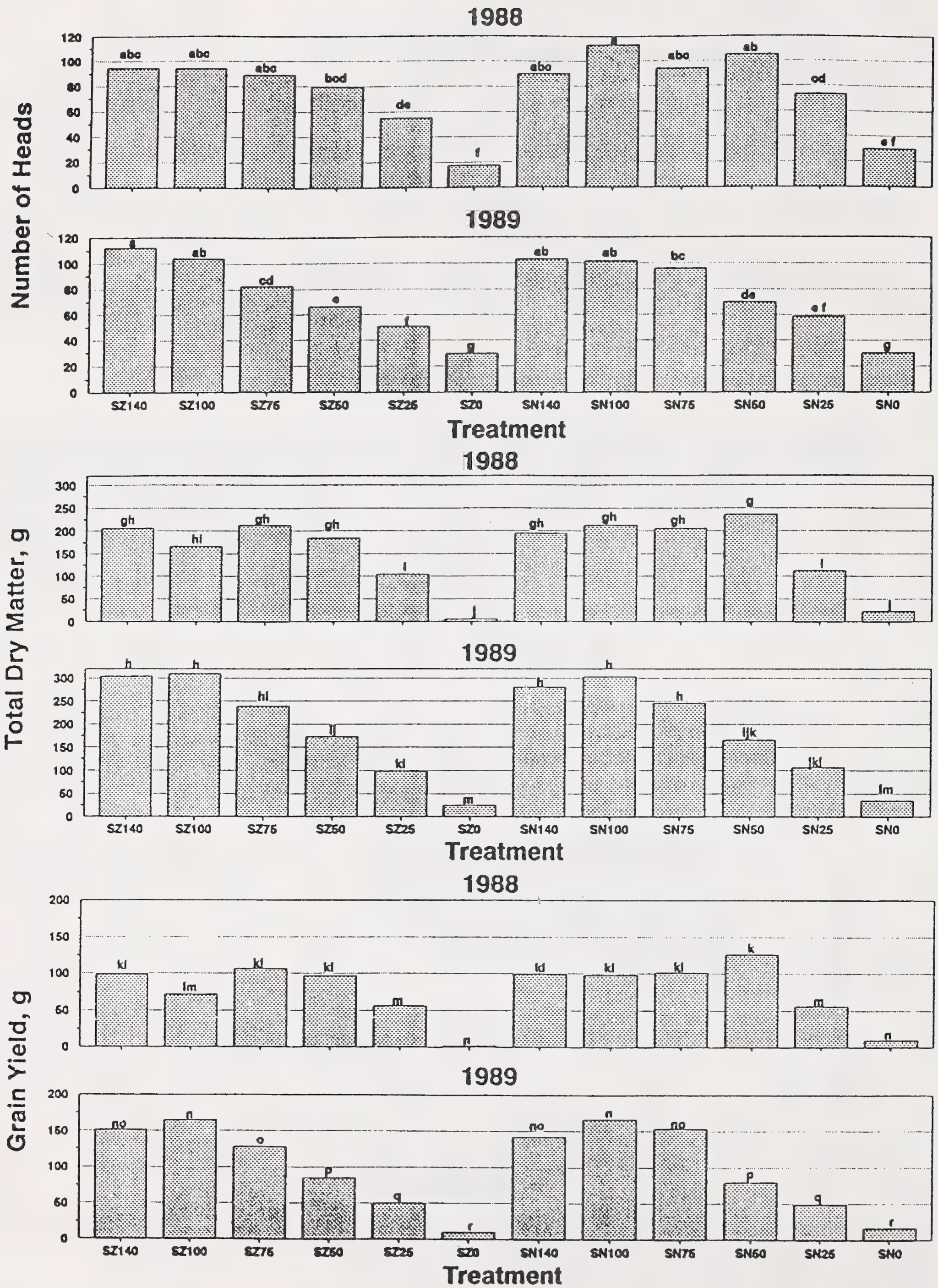


Figure 2. Mean barley yield in 1988 and 1989 (Values for a given year denoted by the same letter are not significantly different, $p < 0.05$).

year study ranged from 657 mm for the SZ0 treatment to 2032 mm for the SN75 treatment.

Statistically significant differences in each of the crop yield parameters were generally not detected in treatments having at least 0.50 to 0.75 m of nonsaline soil (Fig. 2). Yields were somewhat higher in 1989 than in 1988, with maximum grain, total dry matter and number of heads of 167 g, 310 g and 112 heads, respectively in 1989.

Dramatic yield depression was apparent for the SN0, SZ0, SN25 and SZ25 treatments in both 1988 and 1989 (Fig. 2). Barley yield in 1988 on the SN50 and SZ50 treatments was not statistically different from treatments containing a greater depth of nonsaline soil. Yield in 1989 on the SN50 and SZ50 treatments was approximately 50 percent of the yield obtained on treatments containing a greater depth of nonsaline soil.

The positive, linear relationships observed between each of the crop yield parameters and water use (Fig. 1) indicate that crop yield was dramatically reduced when inadequate supplies of soil moisture were available within the root zone of treatments having a shallow depth to saline-sodic subsoil. These findings are consistent with existing theories concerning the linear relationship between relative dry matter yield and the ratio of transpiration to potential transpiration (de Wit 1958; Childs and Hanks 1975; Bresler and Hoffman 1986).

Salt Redistribution

Statistically significant changes in salinity and sodicity within the different lysimeter treatments (Table 1) indicate that substantial leaching of soluble salts occurred in all treatments except the nonsaline controls. The irrigation management regime implemented generally resulted in a statistically significant decrease in the soluble salt content of the saline-sodic and solonetzic subsoil materials. Salt redistribution was dominated by the more readily soluble magnesium and sodium sulfate, bicarbonate and chloride salts (Data not shown).

Reclamation of soils characterized by highly saline-sodic subsoils may be achieved through adequate control of the water table and subsequent leaching of excess salts, provided internal drainage characteristics of the soil permit water movement through the profile within a reasonable time frame. Scheduling irrigation on the basis of 0.5 m tensiometer readings resulted in substantial leaching of soluble salts to lower depths. Significant reductions in soil salinity and sodicity in the saline-sodic subsoil material resulted from the redistribution of surplus irrigation water to the lower portion of the root zone. The quantity of water needed for reclamation depends to a great extent on initial soil salinity, with about 80 percent of the soluble salts in a soil profile removed through leaching with an equivalent depth of water (Hoffman et al. 1983). Harker and Mikalson (1990) detected an average salinity reduction of about 75 percent in soil cores from Solonetzic soils in southern Alberta that were leached in the laboratory, when an equal depth of water was applied to the depth of soil to be reclaimed.

## CONCLUSIONS

Barley yield in irrigated lysimeters characterized by different depths to saline-sodic subsoil was not significantly reduced in treatments having a minimum of 0.75 m of nonsaline material within the upper soil profile. The irrigation management regime implemented in this experiment provided for net

Table 1. Changes in soil salinity and sodicity in each treatment from 1987 to 1989

| | | Saline-Sodic Subsoil Treatments | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SN0 | | SN25 | | SN50 | | SN75 | | SN100 | | SN140 | |
| Parameter | Depth, m | 1987 | 1989 | 1987 | 1989 | 1987 | 1989 | 1987 | 1989 | 1987 | 1989 | 1987 | 1989 |
| ECe, dS $m^{-1}$ | 0.00 - 0.25 | 21.47 | 6.32** | 1.13 | 1.22 | 1.71 | 0.71 | 1.13 | 1.41 | 1.10 | 0.93 | 1.33 | 0.78 |
| | 0.25 - 0.50 | 21.43 | 10.74** | 22.93 | 7.09** | 1.54 | 1.03 | 1.11 | 1.04 | 1.11 | 0.67* | 1.05 | 0.70** |
| | 0.50 - 0.75 | 21.57 | 15.23** | 22.87 | 15.43** | 23.00 | 7.07** | 1.13 | 2.06 | 1.09 | 1.16 | 1.04 | 0.75 |
| | 0.75 - 1.00 | 22.70 | 20.23 | 22.23 | 24.87 | 22.87 | 15.53* | 22.13 | 6.81** | 1.19 | 2.72 | 1.11 | 1.01 |
| | 1.00 - 1.40 | 21.07 | 23.60 | 22.60 | 28.17* | 22.87 | 23.57 | 23.47 | 14.99 | 22.33 | 9.65* | 1.04 | 1.14 |
| Total ECe, dS $m^{-1}$ | 0.00 - 1.40 | 108.24 | 76.12** | 91.76 | 76.78* | 71.99 | 47.91* | 48.97 | 26.31* | 26.82 | 15.13 | 5.57 | 4.38 |
| SAR | 0.00 - 0.25 | 31.60 | 9.01** | 0.37 | 1.84** | 0.80 | 0.80 | 0.37 | 1.04 | 0.40 | 0.73 | 0.53 | 0.49 |
| | 0.25 - 0.50 | 31.67 | 18.88** | 32.97 | 11.69** | 0.70 | 1.20 | 0.33 | 0.94* | 0.33 | 0.47 | 0.37 | 0.50 |
| | 0.50 - 0.75 | 30.97 | 26.63 | 33.47 | 29.93 | 33.67 | 10.92 | 0.40 | 1.24** | 0.30 | 0.83 | 0.33 | 0.38 |
| | 0.75 - 1.00 | 31.80 | 31.04 | 33.37 | 35.28* | 32.27 | 29.56 | 33.90 | 1.91** | 0.33 | 3.29 | 0.37 | 0.49 |
| | 1.00 - 1.40 | 31.23 | 32.93 | 33.67 | 35.31 | 33.63 | 35.15 | 35.13 | 2.30** | 33.73 | 16.54* | 0.37 | 0.47 |

| | | Solonetzic Subsoil Treatments | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SZ0 | | SZ25 | | SZ50 | | SZ75 | | SZ100 | | SZ140 | |
| Parameter | Depth, m | 1987 | 1989 | 1987 | 1989 | 1987 | 1989 | 1987 | 1989 | 1987 | 1989 | 1987 | 1989 |
| ECe, dS $m^{-1}$ | 0.00 - 0.25 | 19.13 | 5.77** | 1.12 | 1.31 | 1.14 | 0.77* | 1.82 | 0.62 | 1.16 | 1.38 | 1.60 | 0.72 |
| | 0.25 - 0.50 | 18.93 | 9.90** | 19.43 | 4.36** | 1.14 | 0.80 | 1.13 | 0.61** | 1.18 | 0.91 | 1.69 | 0.98* |
| | 0.50 - 0.75 | 20.70 | 12.42* | 19.57 | 8.52** | 20.33 | 3.98** | 1.13 | 1.04 | 1.19 | 0.72* | 1.25 | 0.89 |
| | 0.75 - 1.00 | 19.10 | 15.20* | 21.03 | 12.39* | 21.13 | 9.22** | 21.53 | 4.56** | 1.18 | 1.86 | 1.19 | 0.84 |
| | 1.00 - 1.40 | 19.93 | 16.80 | 20.90 | 17.77* | 21.13 | 15.97* | 20.87 | 9.74* | 19.80 | 8.72* | 2.14 | 0.89 |
| Total ECe, dS $m^{-1}$ | 0.00 - 1.40 | 97.79 | 60.09** | 82.05 | 44.35** | 64.87 | 30.74** | 46.48 | 16.57** | 24.51 | 13.59* | 7.87 | 4.32 |
| SAR | 0.00 - 0.25 | 33.30 | 10.32** | 0.43 | 2.00* | 0.33 | 0.65 | 1.07 | 0.55 | 0.30 | 1.24 | 0.77 | 0.54 |
| | 0.25 - 0.50 | 32.47 | 19.41** | 33.97 | 7.81** | 0.47 | 1.02 | 0.33 | 0.52 | 0.37 | 0.72* | 0.90 | 0.81 |
| | 0.50 - 0.75 | 34.63 | 24.20* | 33.77 | 16.45** | 35.33 | 8.78** | 0.33 | 1.47* | 0.30 | 0.53* | 0.40 | 0.62 |
| | 0.75 - 1.00 | 33.93 | 28.57* | 35.20 | 24.95** | 35.07 | 18.62** | 33.37 | 8.29** | 0.30 | 2.21** | 0.37 | 0.40 |
| | 1.00 - 1.40 | 33.47 | 30.40 | 35.07 | 31.79 | 34.13 | 29.62 | 33.70 | 18.80* | 34.23 | 15.77 | 1.53 | 0.43 |

Based on a paired t-test, where n = 3 and differences between years are significant at $p < 0.05$ (*) or $p < 0.01$ (**).

downward movement of soil water and resulted in substantial leaching of soluble salts, even in the treatments having a shallow depth to saline-sodic subsoil. Irrigation management practices may compensate for soil limitations associated with high levels of subsoil salinity, provided sufficient water is applied to promote net downward movement of water through the root zone without resulting in the build-up of a water table within less than about 1.5 m of the soil surface.

Modification of existing land classification standards to permit extensive development of land characterized by shallow, saline-sodic subsoils is presently not recommended due to the high level of irrigation management required to overcome these soil limitations, the increased environmental hazards associated with development of marginal land containing large amounts of soluble salts and given the abundance of land that is currently suitable for irrigation development with the extremely limited water supplies available in southern Alberta.

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## A COMPARISON OF RECHARGE UNDER IRRIGATED AND NON-IRRIGATED TREATMENTS

J. Rodvang and D. Mikalson[1]

### INTRODUCTION

The characterization of groundwater recharge is important for the prediction of the long-term quality of surface water, groundwater and soils. Therefore, an investigation was conducted to compare ground-water recharge under irrigated and non-irrigated conditions in southern Alberta. The study was initiated in 1988 at a site located approximately 20 km east of Milk River.

### THE STUDY AREA

The study area was composed of three quarter sections, with a centre pivot on each quarter. The parent material was till and the water table was at approximately 21 m depth. A total of 18 monitoring locations were located on the site, as follows: three under each pivot, and nine in the non-irrigated corners of the study area. During both sampling years, the two outer pivots were under cereal crops and the central pivot was under alfalfa. Control areas were under soft wheat in 1990, and fallow in 1991. A more complete description of the study area is contained in Rodvang (1991).

Although monitoring began in 1988, methods and sampling locations were changed in 1989, and therefore, results and discussion will be limited to data gathered during the 1990 and 1991 growing seasons.

### METHODS OF INVESTIGATION

Since 1988, major ion concentrations have been determined using saturation paste extract tests (Rhoades, 1982), on soil samples collected in the spring and fall of each year. In 1989 neutron access tubes were installed to the depth of auger refusal (2.5 to 4.5 m) at all sampling sites. Moisture content was measured with a Campbell Scientific neutron probe on a biweekly to monthly basis throughout the growing seasons of 1989, 1990 and 1991.

Continuous records of precipitation and irrigation were collected at the site using dataloggers on rain gauges. During March of 1991 gravimetric samples were collected for the purpose of calibrating the neutron probe to actual moisture content. The process was repeated in January 1992 using a Troxler gauge in addition to the Campbell Scientific gauge.

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Neutron probe readings ranged from 5 to 15% higher than corresponding gravimetric readings, on a moisture content by volume basis. Both attempts at calibration gave a very poor correlation between gravimetric and neutron probe readings. However, the Campbell Pacific and Troxler gauges were closely correlated. Therefore, a previous calibration obtained for the Troxler (Chanasyk and McKenzie, 1986) was used to calibrate the Campbell Pacific gauge.

Moisture content at field capacity was estimated using measured grain size in a formula developed by Oosterveld and Chang (1980). For samples below 1.35 m, the depth factor in the formula was held constant.

Soil cores were collected at four locations during November 1991, and enriched tritium was measured by the Environmental Isotope Laboratory in Vegreville. Due to the very dry nature of the soils, the water extraction procedure was extremely difficult and time-consuming. Therefore, only four samples were analyzed.

## RESULTS

Results from the monitoring of soil chemistry with time confirmed the results obtained in 1990 (Rodvang, 1991). Leaching depth and absolute concentration levels for major ions varied over short lateral distances, and no consistent changes in time were noted at any sampling locations.

Irrigated sites received just over 200 mm more water than non-irrigated sites in both monitoring years. Approximately 250 mm of rain was received during each of 1990 and 1991. The average moisture content at each site was similar between the two years, although at many sampling locations moisture content tended to be slightly higher above 2 m in 1990. The change from crop to fallow under control areas caused near-surface moisture content to increase in 1991 at those locations.

The seasonal variation in moisture content is illustrated for a typical sampling location in Figure 1. Moisture contents generally decreased during the summer of 1990, and showed an increase in moisture when monitoring resumed in March, 1991. Prominent spikes in moisture content occurred following a rainfall event in May, with lesser spikes following an irrigation event in July. Surface readings showed the greatest response to precipitation, but minor fluctuations were also seen at depth (Figure 1).

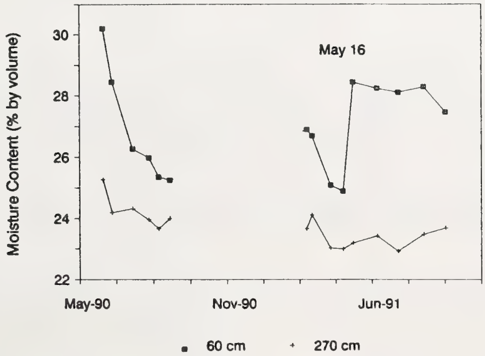


Figure 1: Seasonal Variation in Moisture Content at Site 4C

Results of a comparison of mean moisture content among treatments over the 1990-1991 period were similar to those found in 1990 (Rodvang, 1991). Irrigated cereal crops showed the highest moisture content above 2 m (up to 4% higher than the average under control sites), and alfalfa showed the lowest moisture content above 2.5 m (up to 7% lower than the average for irrigated cereal crops). Below 2.5 m, moisture content was similar under all treatments.

Soil moisture content, averaged over all monitoring dates for each treatment, is compared to estimated field capacity in Figure 2. Moisture contents were generally slightly below field capacity, with the exception of the 1.5 to 3 m depth interval under the irrigated cereal treatment. Moisture content under the alfalfa treatment was the farthest below field capacity.

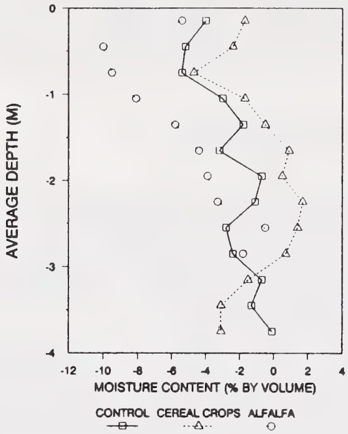


Figure 2: Average moisture content per plot, relative to field capacity

Results of the tritium analysis are summarized in Table 1.

Table 1: Tritium Results

| SITE | TREATMENT | DEPTH (m) | TRITIUM (Tritium Units) |
|---|---|---|---|
| 3A | Alfalfa | 2.5 | 103 |
| 4C | Cereal | 4.5 | 20 |
| 5C | Control | 5.3 | 7.4 |
| 5B | Control | 7.0 | 7.6 |

Tritium levels of more than 100 tritium units (TU) occur only in groundwaters recharged between 1957 and 1971 (Robertson and Cherry, 1989). Therefore, as a rough estimate, it can be assumed that the 1963 tritium peak occurs somewhere around 2.5 m. Based on this assumption, the transit-time method (Daniels et al., 1991), yields a recharge rate of about 2 cm/a, or approximately 6% of annual precipitation.

## DISCUSSION

The small changes in moisture content at depth indicate that some water is recharging below the root zone. Comparisons of mean moisture content among treatments indicate that irrigation over cereal crops at this site does increase moisture content to a depth of 2 m. However, below 2.5 m, no differences were detected between treatments. It is possible that differences in moisture content are homogenized by lateral movement of recharge water below the root zone (Schuh and Klinkebiel, 1991). Alternatively, the water may be lost through evaporation and evapotranspiration.

Irrigation management has an important impact on recharge rates. Recharge is expected to be less under centre pivots than under side wheel rolls or flood irrigation, because water is applied more evenly and over longer time periods. In addition to water application rates, recharge rates are also dependent on microtopography and vegetation. Non-irrigated sites were fallow in 1991, which would promote recharge relative to the cropped irrigated sites. The effect of high-moisture-use crops is demonstrated by the substantially lower moisture content below the alfalfa field. Recharge depends on antecedent moisture conditions, and tends to be event-oriented. Therefore, monitoring over one or two years often does not adequately characterize the long-term behavior of recharge.

## CONCLUSIONS

A comparison of moisture contents to estimates of field capacity based on texture indicated that recharge during the growing season was very low. Minor fluctuations in soil moisture content at depth indicated that some recharge occurred, and tritium profiles suggested that the long-term recharge rate was approximately 2 cm/a. Irrigation over cereal crops caused an increase in soil moisture content in the upper 2 m. Moisture contents below irrigated alfalfa were lower than those under both irrigated cereal crops and non-irrigated fallow areas.

## FUTURE WORK

Gravimetric samples should be compared to neutron probe readings over very shallow depth increments (10 cm) in order to improve the calibration of the neutron probe to actual moisture content. In situ measurements of field capacity and unsaturated hydraulic conductivity would provide for more accurate estimates of recharge rates, as would more detailed tritium profiles. Monitoring of moisture during the winter would provide a more complete picture of annual recharge rates.

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# THE INFLUENCE OF DRAIN DEPTH ON RECLAMATION OF A SALINE-SODIC SOIL UNDER CONVENTIONAL SPRINKLER IRRIGATION

D. Mikalson[1]

## INTRODUCTION

The effect of drain depth and spacing studied at two sites in southern Alberta concluded drains at 0.76 m (5.5 m spacing), 1.22 (7.5 m spacing) and 1.68 m (9.0 m spacing) were equally effective for removal of excess water applied through irrigation, but the 1.22 m and 1.68 m drains were superior to 0.76 m depth for salinity control (Buckland et al. 1985). These conclusions were based on two seasons of intensive leaching and the question remained as to whether normal irrigation could maintain or enhance initial reclamation. This report presents reclamation monitoring results after seven years of normal irrigation management for one of these sites near Nobleford, Alberta.

## METHODS AND DISCUSSION

Soil samples were collected in the fall (or winter) for seven seasons following two years of post drainage leaching. Sampling intervals and analysis procedures were those described by Buckland et al. (1985). Detailed records of precipitation, irrigation management or water-table response were not collected. The alfalfa present during initial leaching was removed and from 1985 to 1991, inclusive, the area has been seeded to barley. The site has been irrigated in all years except 1985 with a sideroll sprinkler system.

Nested (rep within treatment) multiway ANOVA crossed with time and the resulting F-statistic (SAS 1988) indicated electrical conductivity ($EC_e$) and sodium adsorption ratio (SAR) means did not differ between drain treatments or treatment versus time interactions for any depth increment but were significantly different between sampling times. Data for drain treatments were grouped and multiple range tests (Tukey, $p=0.05$) were applied to examine differences in mean $EC_e$ and SAR between sampling times for each depth increment (Tables 1 and 2).

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Table 1. Mean $EC_e$ by time at Nobleford drainage depth/spacings research site.

| | pre-leaching | intensive leaching | | --------conventional side-roll sprinkler irrigation-------- | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Season | | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
| Sampling Date | 830115 | 831115 | 841215 | 860315 | 861215 | 871215 | 881115 | 900123 | 901115 | 911104 |
| Depth Interval | $EC_e$ | $EC_e$ | $EC_e$ | $EC_e$ | $EC_e$ | $EC_e$ | $EC_e$ | $EC_e$ | $EC_e$ | $EC_e$ |
| 0.0 - 0.2 m | 16.0a | 7.5b | 6.2b | 4.0cd | 5.6bc | 5.0c | 4.4cd | 1.7d | 1.8d | 2.1d |
| 0.2 - 0.4 m | 16.2a | 15.5a | 8.8bc | 8.2bc | 9.9b | 8.9bc | 8.8bc | 7.3bc | 8.3bc | 6.1c |
| 0.4 - 0.8 m | 16.4a | 15.8ab | 11.6cd | 9.8cd | 12.8bc | 10.7cd | 10.5cd | 9.0d | 9.8cd | 10.3cd |
| 0.8 - 1.2 m | 16.2a | 16.6a | 14.4ab | 12.6bc | 13.7abc | 12.3bc | 11.4bc | 11.1c | 10.8c | 11.9bc |
| 1.2 - 1.6 m | 14.5abc | 16.8a | 15.1ab | 12.9bcd | 13.2bcd | 12.6bcd | 11.4cd | 11.5cd | 11.2d | 11.8cd |
| 1.6 - 2.0 m | 12.0abc | 13.8a | 13.4ab | 13.1ab | 11.8abc | 11.3abc | 10.4c | 11.4abc | 11.2bc | 10.0c |

row means ($EC_e$ by date) followed by the same letter do not differ significantly (Tukey p=0.05)

Table 2. Mean SAR by time at Nobleford drainage depth/spacings research site

| | pre-leaching | intensive leaching | | --------conventional side-roll sprinkler irrigation-------- | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Season | | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
| Sampling Date | 830115 | 831115 | 841215 | 860315 | 861215 | 871215 | 881115 | 900123 | 901115 | 911104 |
| Depth Interval | SAR | SAR | SAR | SAR | SAR | SAR | SAR | SAR | SAR | SAR |
| 0.0 - 0.2 m | 22.0a | 6.2b | 6.5ab | 6.0bcd | 6.9a | 7.6a | 5.5bcd | 2.6d | 3.0cd | 3.3cd |
| 0.2 - 0.4 m | 23.7a | 18.3b | 11.2cde | 13.4bcde | 15.6bcd | 15.7bc | 14.3bcde | 10.3de | 14.6bcde | 9.5e |
| 0.4 - 0.8 m | 24.9a | 20.6abc | 18.2bcd | 17.3cd | 21.4abc | 22.6ab | 19.3bcd | 15.7d | 19.8bcd | 18.7bcd |
| 0.8 - 1.2 m | 24.8a | 24.4a | 23.4ab | 20.2ab | 22.3ab | 23.8ab | 21.2ab | 19.4b | 21.9ab | 20.6ab |
| 1.2 - 1.6 m | 22.9 | 24.2 | 21.9 | 22.3 | 21.8 | 22.0 | 20.6 | 20.5 | 22.1 | 20.5 |
| 1.6 - 2.0 m | 19.5 | 20.5 | 19.6 | 20.5 | 19.9 | 20.6 | 17.6 | 20.6 | 20.9 | 17.5 |

row means (SAR by date) followed by the same letter do not differ significantly (Tukey p=0.05)

## CONCLUSIONS

After seven years of normal irrigation management following two years of intensive leaching, drain depths of 0.76 m, 1.22 m and 1.68 m were found to be equally effective in reclamation of saline-sodic soils. Monitoring results did not support the initial conclusions of Buckland et al. (1985), that 0.76 m drains would be less effective and 1.68 m drains more effective for salinity control. $EC_e$ means that were improved by 62%, 46% and 30% (of pre-leaching $EC_e$) as a result of intensive leaching were further improved under normal irrigation to 87%, 62% and 37% for depth intervals of 0.0-0.2 m, 0.2-0.4 m, and 0.4-0.8 m, respectively. In the lower profile, $EC_e$ means that were not initially improved were improved by 27%, 18% and 17% for depth intervals of 0.8-1.2 m, 1.2-1.6 m, and 1.6-2.0 m, respectively. Improved $EC_e$ levels were generally maintained under normal irrigation management.

Similarly, SAR means were improved to a depth of 0.8 m after initial leaching and were further improved under normal irrigation

(Table 2). However, while improvements in SAR were smaller, increases were larger, of longer duration and slower to recover than was observed for $EC_e$. After seven seasons of normal irrigation management, SAR means were not different from levels achieved by initial leaching (1984) except in 0.0-0.2 m depth interval.

While mean $EC_e$ improved to levels that would qualify these soils as suitable for irrigation; nine years after drainage, SAR's means remain unacceptable. Without considering spatial variability, it appears unlikely that SAR will achieve an acceptable irrigation criteria within the 10 years allowed by the Class 5R standard (Alberta Agriculture 1983).

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# SOIL SALINITY AND SODICITY LEVELS IN LAND IRRIGATED WITH WATER FROM VERDIGRIS LAKE

K. M. Riddell[1]

## INTRODUCTION

Approximately 850 ha of land are irrigated using water from Verdigris Lake. The quality of the water in Verdigris Lake has electrical conductivities (EC's) ranging from 0.2 to 1.7 dS/m during the irrigation season and, according to Alberta Agriculture guidelines, is classified as "Safe" to "Possibly Safe" (Alberta Agriculture 1983). Long-term use of slightly saline irrigation water has the potential to cause a build up of salts in soil profiles if adequate leaching water and internal drainage are not available. In addition, the long-term impact of irrigating with slightly sodic water in a prairie climate on soil structure is not well understood. Previous investigations have demonstrated the use of marginal quality irrigation water has increased soil salinity and sodicity levels on irrigated land around the lower end of the lake (McMullin et al. 1984; UMA Engineering 1988). Both of these studies considered data from only one sampling date and were not designed for repeated sampling.

In response to these concerns, the Land Evaluation and Reclamation Branch of Alberta Agriculture established benchmark sites to monitor the long-term impact of irrigation with marginal quality water on soil quality. The specific objective of this report is to document the impact of irrigation with marginal quality water on soil salinity and sodicity levels.

## METHODS

Soil samples were taken from both irrigated and dryland treatments at five sites in the fall of 1990. Four of the sites (A, B, C and D) were using irrigation water from various locations along Verdigris Lake (Figure 1) and the fifth site (E) used irrigation water from the Milk River. Salinity and sodicity levels in irrigation water used at site A were around 0.3 dS/m and 0.9, respectively. Salinity and sodicity levels in irrigation water used at sites B and C were around 1.4 dS/m and 6.0, respectively. Salinity and sodicity levels in irrigation water used at site D were around 1.6 dS/m and 7.0, respectively. Water quality in the Milk River was very similar to water quality in irrigation canals in the irrigation districts of southern Alberta, where the average EC and SAR were 0.4 dS/m and 0.5, respectively.

All sites were pivot irrigated with the exception of site B which was irrigated by either a towable pivot or a sideroll sprinkler system.

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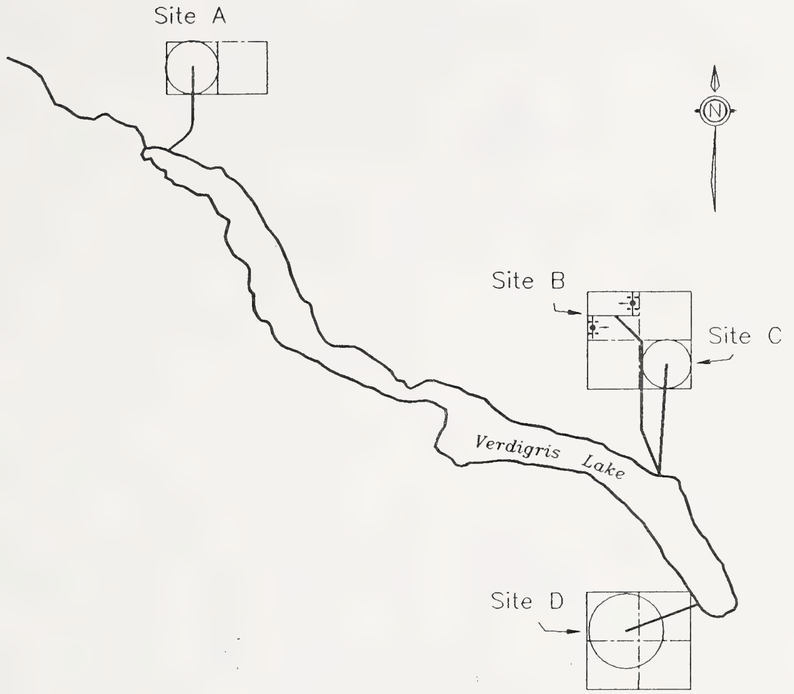


Figure 1. Site location map for Verdigris Lake soil and water quality study.

system. Under both pivot and sideroll irrigation, four plots were located within the irrigated area and four plots were established in the dryland corners adjacent to the pivot, and an adjacent dryland quarter in the case of the sideroll (Riddell 1990).

Each irrigated and dryland plot had four soil sampling locations, giving a total of 16 soil sampling locations under the irrigated and dryland treatment at each site. Soils were sampled in 15 cm increments to a depth of 30 cm and in 30 cm increments between 30 and 120 cm depths. Soil profiles were described at each sampling location. Soil samples were analyzed for electrical conductivity (EC) and sodium adsorption ratio (SAR) according to standard methods (Rhoades 1982).

Statistical analyses consisted of comparing treatment means (irrigated vs dryland) at each site using unpaired t-tests, based on 16 soil sampling locations at all sites except site A where there was only 12 soil sampling locations.

## RESULTS AND DISCUSSION

Soil EC levels in the 0 - 15 cm depth for the irrigated treatment at all sites were significantly higher than the dryland treatment (Figure 2). Soil EC levels in the 15 - 30 and 30 - 60 cm depth

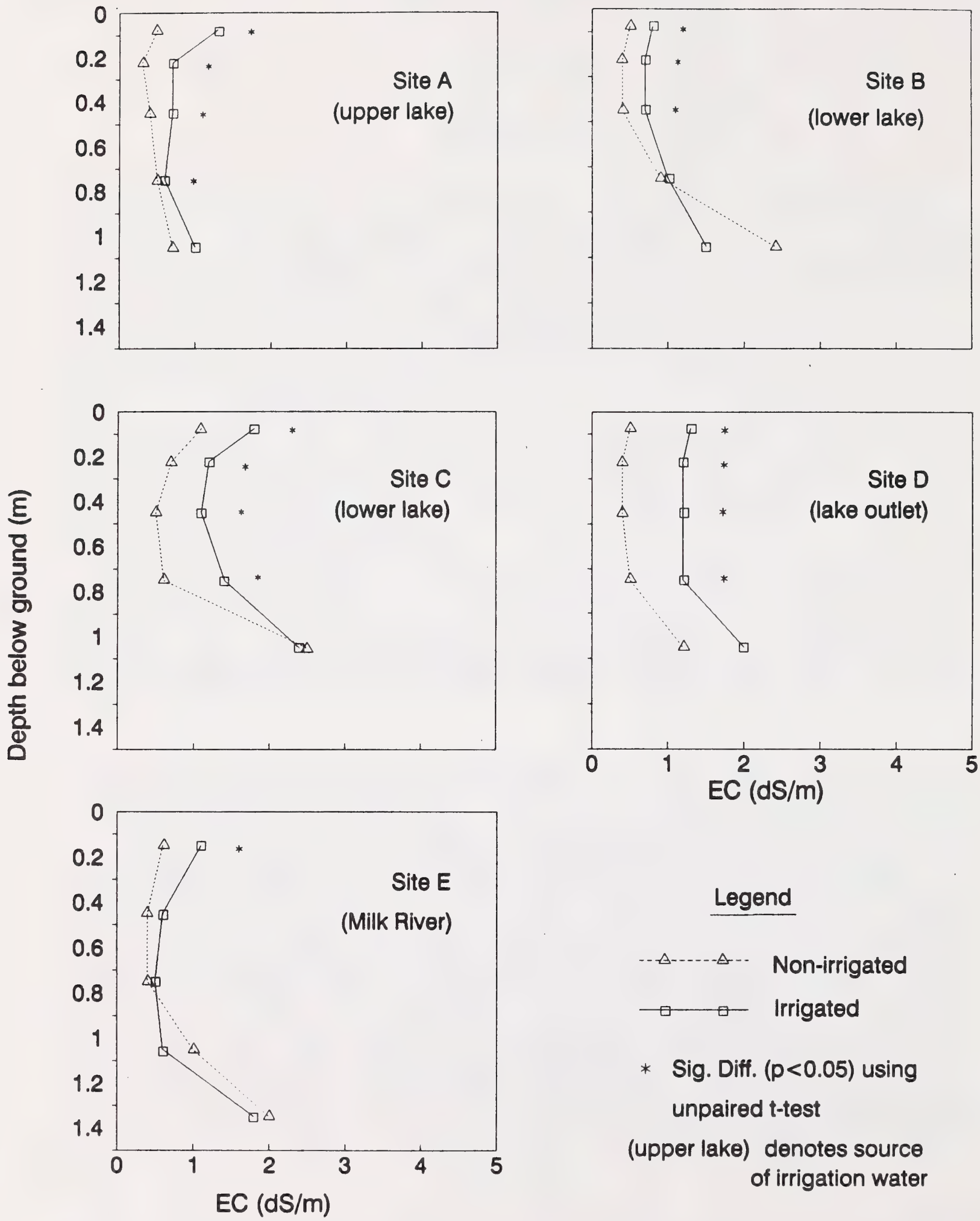


Figure 2. Soil EC vs depth for four sites irrigated from Verdigris Lake and one site irrigated from the Milk River.

increments at all sites irrigated from Verdigris Lake were significantly higher than the dryland treatment (Figure 1). The largest EC increases were observed to the greatest depths at sites C and D, which used irrigation water from the lower or outlet end of Verdigris Lake. Soil EC levels in the upper 90 cm at sites C and D were very similar to the EC levels in the water at the outlet end of Veridgris Lake (Figure 2).

The increases in soil EC observed from using marginal quality irrigation water at the lower end of Verdigris Lake were not of sufficient magnitude to cause problems for crop growth. Salt concentrations in the upper 90 cm of the soil profile at site D appeared to be in equilibrium with the irrigation water being withdrawn from the outlet end of the lake. This would indicate that, to date, leaching from rainfall and irrigation prevented the build up of salts in excess of the concentration of the irrigation water. Maintenance of a favorable, long-term salt balance in irrigated soil profiles at the outlet end of the lake appears to depend heavily on favorable spring and fall rains.

Soil SAR levels in the 0 - 15 and 15 - 30 cm depths for the irrigated treatment at all sites were significantly higher than for the dryland treatment (Figure 3). However, the increases in soil SAR in the upper profile were much larger at the sites irrigated from Verdigris Lake, particularly at sites C and D (Figure 3). Soil SAR levels in the upper profile (0 - 45 cm) at sites irrigated out of Verdigris Lake were very similar to the SAR of the lake water.

The increases in soil SAR at sites C and D, which were irrigated with marginal quality water from the lower end of Verdigris Lake, were of sufficient magnitude to cause concern about possible negative affects on soil structure. Minhas and Sharma (1986) reported significant reductions in hydraulic conductivity in clay loam soils with an SAR of 5, when soils were irrigated with marginal quality water and subsequently irrigated with good quality rainwater. The addition of rainfall lowers the electrolyte concentration in soil pores and causes dispersion if sufficient levels of sodium are present on the exchange complex. Curtin et al. (1989) also state that the combined effects of dilution and mechanical effects of a severe rainstorm could cause extensive aggregate breakdown on land irrigated with water of moderately good quality.

## CONCLUSIONS

Irrigation with both good quality water from the Milk River and marginal quality water from the lower end of Verdigris Lake caused statistically significant increases in soil EC and SAR in the upper profile. However, the increases in soil EC and SAR were much greater under irrigation with marginal quality water from the lower end of Verdigris Lake. To date, the increases in soil EC associated with using marginal quality irrigation water were not sufficient to affect crop growth. Maintenance of a favorable, long-term salt balance in irrigated soil profiles at the outlet end of the lake will probably depend heavily on spring and fall rains. Increases in soil SAR in irrigated soil profiles at the lower end of Verdigris Lake were of sufficient magnitude to raise concerns about possible effects on soil

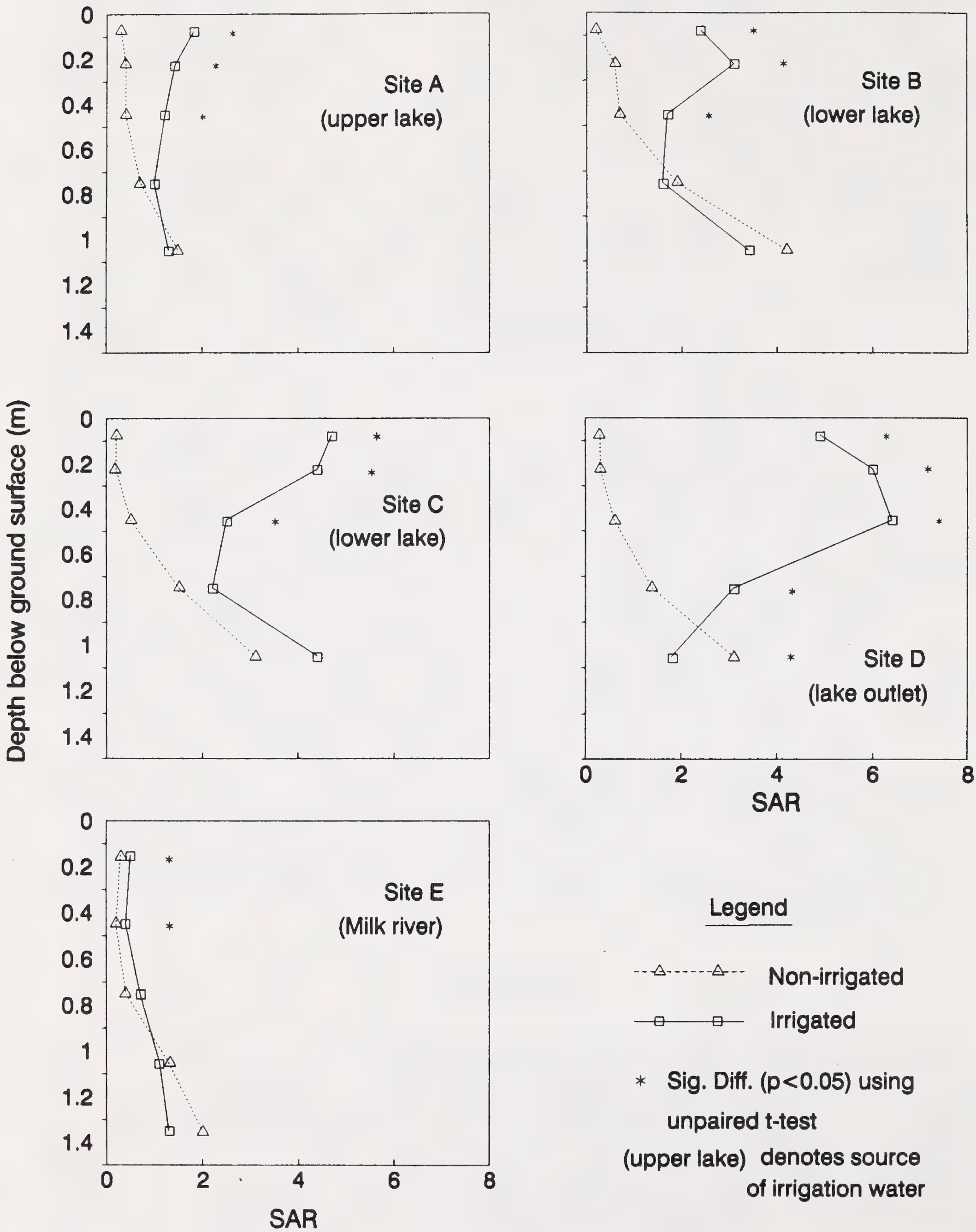


Figure 3. Soil SAR vs depth for four sites irrigated from Verdigris Lake and one site irrigated from Milk River.

structure. Studies conducted elsewhere have pointed to possible problems with reduced aggregate stability and reductions in soil hydraulic conductivity when marginal quality irrigation water is used in combination with fresh rainwater.

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# SOIL SALINITY AND GROUNDWATER LEVELS ADJACENT TO A POLYLINED CANAL IN THE EASTERN IRRIGATION DISTRICT TWO YEARS AFTER CANAL REHABILITATION

K.M. Riddell[1]

## INTRODUCTION

The Irrigation Rehabilitation and Expansion Program (IREP) Reclamation Effectiveness Study represents a continuation of work evaluating the effectiveness of various seepage control measures on saline soil reclamation. The study responds to a need to document reductions in seepage-affected land associated with the existing IREP program (Cooper and Lybrand 1987).

The current study builds on the findings of previous research (Millette et al. 1989; Bennett 1990) and has the following objectives:

1. To provide a landscape model for representative saline/waterlogged areas prior to canal rehabilitation. Soil profile information, near surface stratigraphy (0-4.5 m), water-table conditions, surface drainage, irrigation practices, and available hydrogeological information will be incorporated.
2. To monitor fluctuation of the water table and changes in the spatial and vertical distribution of salts within affected land units following canal rehabilitation.

Because of the large number of canals under investigation in this program only a representative sample was reported here.

## METHODS

The project area was located in the SE 24-16-16-W4 along an irrigation canal in the Eastern Irrigation District (Figure 1). Soil sampling, EM-38 and groundwater monitoring methods used in this study have been previously described (Riddell and Bennett 1989 and Riddell 1990). Soil salinity levels determined by soil sampling/laboratory techniques were done in the Falls of 1989 and 1991 at three plot locations (Figure 1). Soil salinity levels determined by EM-38 techniques were done in the Falls of 1989, 1990, and 1991 at fixed grid locations (Figure 1). Water-table wells were installed on May 5, 1989 and have been monitored biweekly during the irrigation season and monthly from November to April since installation.

Soils in the study area consisted of a mixture of Calcareous and Rego Brown Chernozemic developed on a discontinuous veneer of sandy loam, fluvial material overlying clay loam till. The till was moderately saline-sodic with electrical conductivities (EC) ranging from 2 to 7 dS/m and sodium adsorption ratios (SAR) ranging from 6 to 15.

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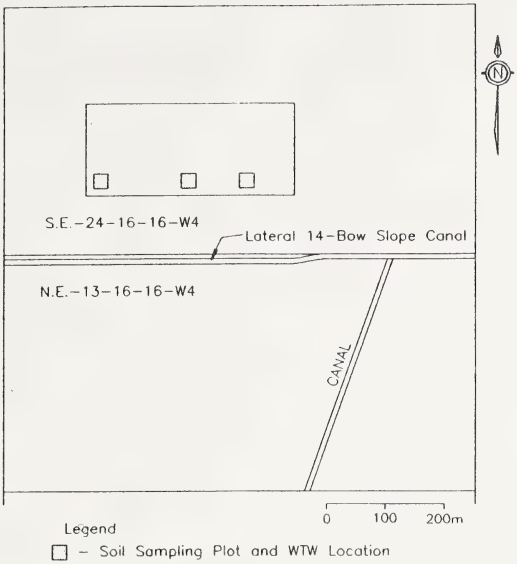


Figure 1. Location plan for soil sampling plots, WTW locations and EM-38 salinity mapping grid.

Solonetzic soils were found in isolated patches where there was no fluvial material covering the till.

## RESULTS AND DISCUSSION

The water table under plots three and four on the north side of the canal has risen in the two years (1990 and 1991) after canal rehabilitation (Figure 2). Higher water tables were attributed to increased rainfall and irrigation applications. May to October rainfall and irrigation amounts for 1989, 1990 and 1991 were 193, 426, and 345 mm, respectively. The water table at this site was in saline/sodic till and has probably developed over the last 90 years of irrigation. The lining of the canal in the winter of 1990 has eliminated sharp water-table rises in association with canal turn on, but irrigation management and climatic fluctuations have exerted a greater influence on water-table fluctuations over the past two years.

In 1991, two years after the installation of the liner, soil salinity levels at plots three, four and five were very similar to 1989, pre-rehabilitation levels (Figure 3). Salinity levels in 1991 were significantly lower than 1989 levels at a single depth (30-60 cm) at plot 4 (Figure 3). Additional water from rainfall and irrigation in 1990 and 1991 has not leached salts to any great extent and has caused shallower water tables.

Fall 1989, 1990, and 1991 salinity contour maps and frequency histograms generated from EC values determined from EM-38 readings show little or no change in salinity over the mapped area (Figure 4). Frequency histograms indicate there were more readings of greater than

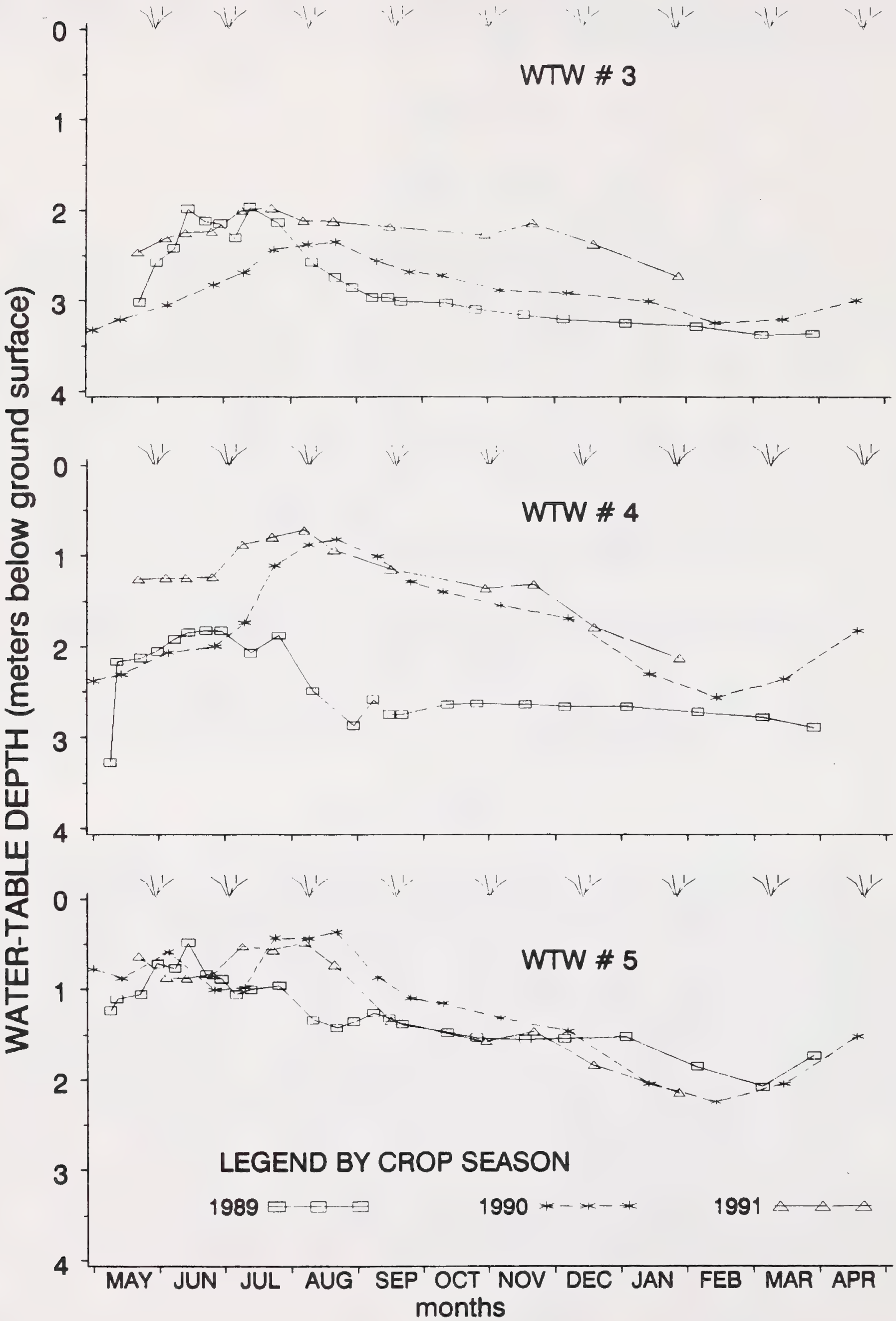


Figure 2. Hydrographs for water-table wells (WTW) 3, 4 and 5 at E.I.D. IREP site.

4 dS/m in 1990 and 1991 after the canal was rehabilitated (Figure 4). Profile salinity levels determined by the EM-38 method were consistently lower than profile salinity levels determined by traditional sampling/lab methods, which was consistent with previous attempts to compare these methods (Riddell 1990).

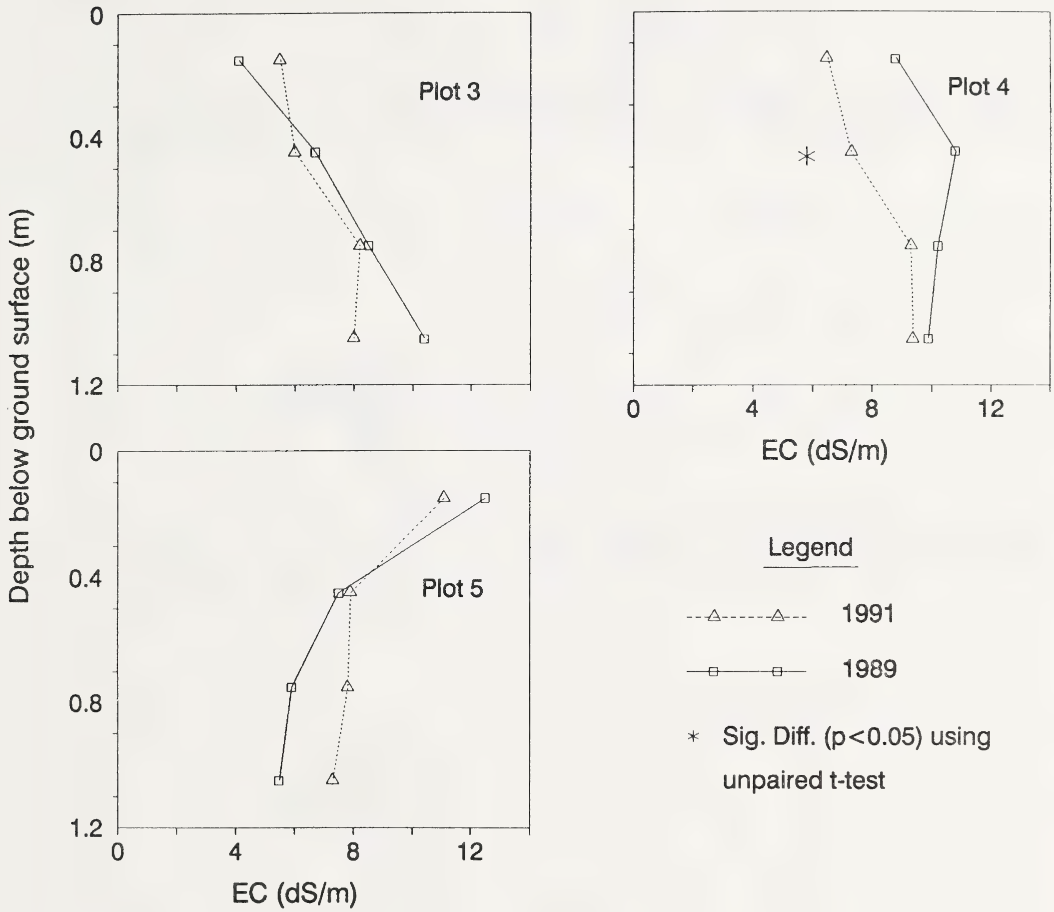


Figure 3. Mean EC (dS/m) vs. depth in soil profile for 1989 and 1991 samples taken at EID IREP reclamation site.

## CONCLUSIONS

Soil salinity and groundwater levels adjacent to a canal in the EID have not declined two years after canal rehabilitation. Lining the canal has eliminated one source of groundwater recharge and has prevented sharp increases in the water table associated with canal turn on. However, irrigation and natural precipitation were still recharging a water table which was perched in a saline/sodic till. Changing irrigation management and improving drainage rates in the

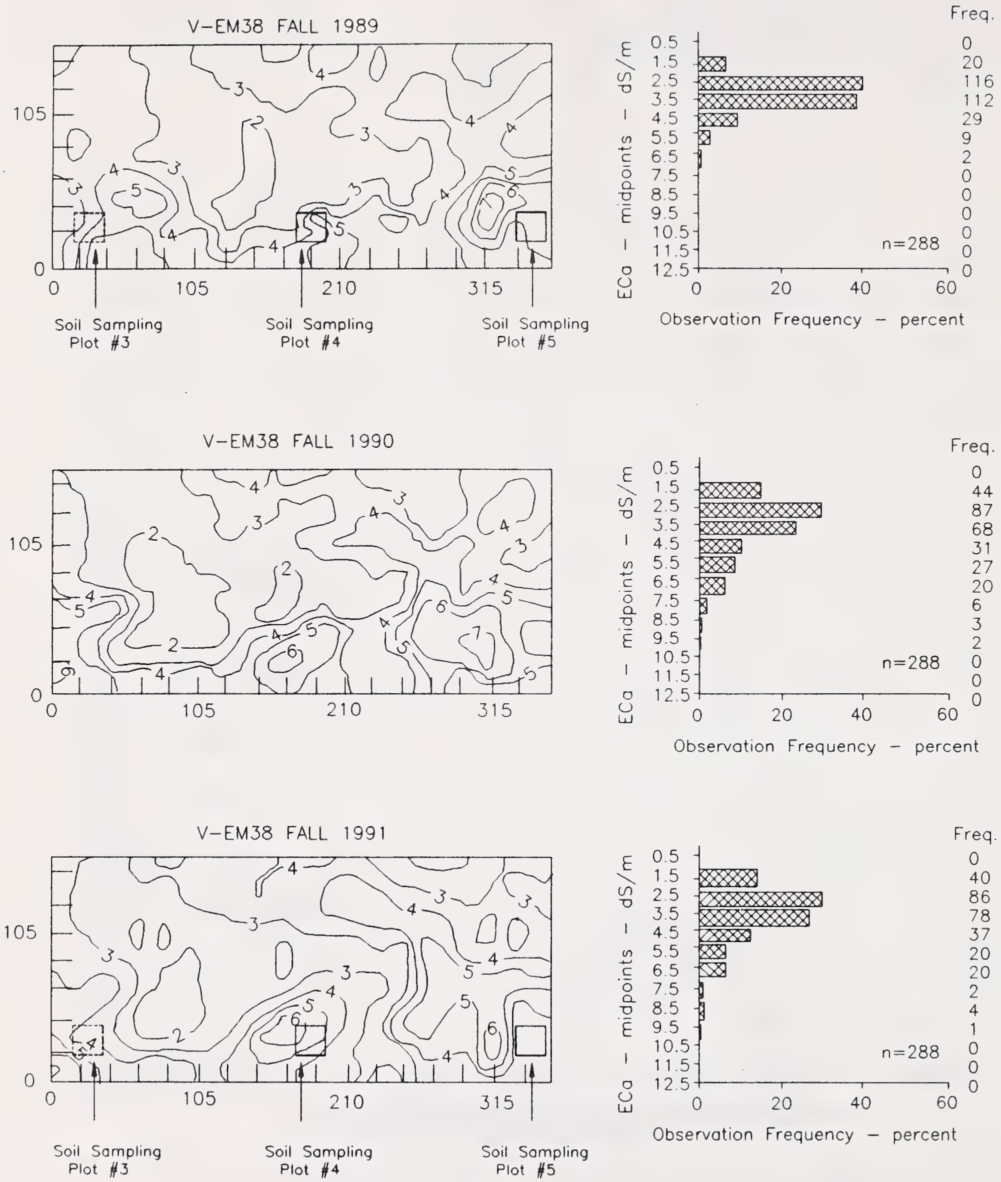


Figure 4. Contour maps and frequency histograms for fall 1989, 1990 and 1991 salinity levels (dS $m^{-1}$) determined by vertical EM-38 readings (V-EM38) on the north side of the canal at the EID IREP reclamation site.

slowly permeable till appear to be the best alternatives for improving salinity levels at this site.

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# SOIL AND GROUNDWATER CHEMISTRY IN IRRIGATED LAND RECEIVING MANURE APPLICATIONS IN SOUTHERN ALBERTA

K. M. Riddell and J. Rodvang[1]

## INTRODUCTION

There is a high concentration of large (> 5,000 head) feedlots in the irrigation districts of southern Alberta because of the favorable climate and secure supplies of water and feed. Long-term applications of feedlot manure at the rate of 60 Mg $ha^{-1}$ on irrigated soils may result in nitrates being leached to groundwater (Chang et al. 1991). In response to this study, the Land Evaluation and Reclamation Branch of Alberta Agriculture initiated a monitoring program to compare soil and groundwater chemistry beneath irrigated, manured fields with adjacent irrigated, non-manured fields at scattered locations across the irrigation districts of southern Alberta.

## METHODS

Nitrate ($NO_3$-N) and chloride (Cl) levels were monitored in soils and groundwater at five sites in four irrigation districts across southern Alberta (Bolseng 1991). Cl was used as a tracer because Cl levels in manure were much greater than background levels in soils, and Cl does not interact with the soil system. Selected trace metals (Zinc (Zn), Copper (Cu), Iron (Fe) and Manganese (Mn)) and phosphate ($PO_4$-P) were also monitored in soils only. Four sampling locations were established along a transect at lower landscape positions in adjacent manured and non-manured fields at each site (Figure 1). A summary of soil-landscape features, water-table depths, irrigation methods, agronomic factors and "estimated" manure application rates for the control and manured treatment at each site is presented in Table 1. Manure application rates were "best guess" estimates obtained from cooperating producers.

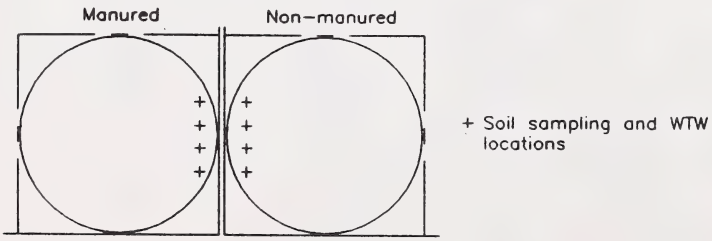


Figure 1. Sampling location plan for manured and non–manured treatments.

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Table 1: Summary of Landscape, Geology & Management Features at each site.

| Site | Treatment | Landform/Soil | Bedrock Depth (m) | Peak Water Table Depth (m) | Irrigation | 1990 Crop | Fertilizer Rate (kg/ha) (Actual Amt) N=Nitrogen; P=Phosphorus | Manure Application Mg/ha Wet Wt. Basis |
|---|---|---|---|---|---|---|---|---|
| B | Manured | undulating glacio-fluvial-eolian overburden, moderately saline, Brown Chernozem | > 3 | 1 - 1.5 | Pivot | Corn | 25 N drilled with seed, light application through pivot in early July | 60 - 120, alternate falls since 1980. Incorporated by discer following spreader. |
| | Control | undulating glacio-fluvial-eolian overburden, Orthic Brown Chernozem | > 3 | 1 - 1.5 | Wheel Roll | Barley | 45 N drilled with seed | ——— |
| C | Manured | Non-saline glaciofluvial material over moderately saline till at 2 to > 3 m. | > 3 | 1.5 - 2.5 | Pivot | Corn | last application was in 1987 | 17-20 annually since 1975, incorporated within 1 week of spreading. |
| | Control | Gleyed Brown Chernozemic or Orthic Humic Gleysolic | > 3 | > 3 | Wheel Move | Wheat | 84 N broadcast & plowed in during April | ——— |
| D | Manured | Glacio-fluvial material over till or bedrock. Sites 1 & 2: Gleyed Dark Brown Solods over saline/sodic till Sites 3 & 4: Orthic Brown Chernozems over blanket glaciofluvial over till | Sites 3-4: 1.7 & 1.9 m | 1.0 - 1.5 | Wheel Move | Rye & Barley mix | 76 N broadcast in the spring & 11 to 17 N & P drilled with the seed | 5 times between 1975 & 1990. Last 2 applications were in the springs Of 1990 & 1985. 1990: 325, not incorporated after spreading. |
| | Control | Glaciofluvial over till or bedrock. Gleyed or Orthic Dark Brown Solodized Solonetz over saline/sodic till with numerous sand lenses | > 3 | 0.8 - 2.0 | Wheel Move | Pasture (20% Alfalfa) | 38 urea N broadcast in the spring | ——— |
| L | Manured | Undulating till plain with pockets of veneer or blanket glaciolacustrine overlying till. Lacustrine deposits 1.2 to 3 m over till. | > 3 | 1.7 | Wheel Move | Barley | 33 N banded in fall of 1989 | 50 during fall of 1987, incorporated within a week of spreading |
| | Control | Calcareous Dark Brown Chernozemic (carbonated phase) | > 3 | 1.0 - 2.0 | Wheel Move | Soft Wheat | 101 N broadcast in spring. | ——— |
| M | Manured | Undulating glaciofluvial & glaciolacustrine deposits over till. | > 3 | 0.71 | Wheel Move | Silage Barley | 90 N (Anhydrous Ammonia) banded in the spring & 67 P drilled with the seed. | 50 - 60 annually since 1987, in late August & disced within 1 week |
| | Control | Saline Dark Brown Chernozemic | > 3 | 1.27 | Wheel Move | Silage Barley | 112 N banded in the spring of 1990 78 N banded in the spring of 1989 | Management: locations 1 & 2: shallow plowed before seeding locations 3 & 4: deep plowed & irrigated before seeding |

Soil $NO_3$-N and Cl levels were determined on saturation extracts using standard methods (Alberta Agriculture 1989). Soil $NO_3$-N was converted from meq/L to kg/ha using bulk densities estimated from saturation percentage. Soil Cl was converted from meq/L to $\mu$g/g dry soil basis using saturation percentage. Water $NO_3$-N and Cl were determined using standard methods (Alberta Agriculture 1989) and were presented in mg/L. Phosphate ($PO_4$-P) determinations were done on ammonium fluoride-sulfuric acid extracts (Miller and Axley 1956) using a colorimetric method (Technicon Industrial Method No. 781-86T 1987). Trace metals were determined on DTPA extracts (Lindsay and Howell 1978) using Inductively Coupled Plasma (ICP) Spectroscopy.

## RESULTS AND DISCUSSION

The largest accumulations of soil $NO_3$-N in the upper (0-0.6 m) and lower (0.0-1.2 m) root zone of all sites occurred under the manured treatment at site B (Table 2). Manure at Site B was applied every second year at rates of 90 - 120 Mg $ha^{-1}$. This was the second highest application rate of all sites. Very large accumulations of soil $NO_3$-N in the upper and lower root zones were also found at site C (Table 2). Manure had been applied annually at low rates (17 - 20 Mg $ha^{-1}$) at site C. Despite having the largest manure application rate (325 Mg/ha) of all sites, the average amount of soil $NO^3$-N accumulated in the upper and lower root zones at site D was the lowest of any site. The manure at site D was applied in the spring and was not incorporated. Substantial amounts of nitrogen were probably lost to volatilization. In addition, the soil was subject to waterlogging during heavy rainfalls in May and June which could have caused significant deinitrification and/or leaching. Site L was unique in that soil $NO^3$-N levels in and below the root zone were higher under the control treatment than under the manured treatment (Table 2). This was attributed to high levels of inorganic nitrogen fertilizer applied to the control treatment during the 1980's.

Soil chloride concentrations in the upper and lower root zones and below the root zone were higher under the manured treatment as compared to the non-manured treatment at all sites (Table 3). As was the case with soil $NO_3$-N, there was not good agreement between application rates and the amount of soil Cl accumulated in or below the root zone. The highest levels of soil Cl below the root zone were found at site C (Table 3). Soil electrical conductivity (EC) and sodium adsorption ratio (SAR) were not higher under the manured treatment as compared to the control treatment, except at site B where the salinity and sodicity may have been present before application of manure commenced (data now shown).

$NO_3$-N levels in groundwater exceeded the drinking water limit (10 mg $L^{-1}$) under the manured treatment at all sites and under the control treatment at sites L and M (Figure 2). Cl levels in groundwater were much higher under the manured treatment as compared to the non-manured treatment at sites B, D, and M (Figure 2).

A consistent pattern emerged when comparing $NO_3$-N and Cl levels in soil and groundwater beneath manured treatments at sites B, C, D, and L. The highest levels of $NO_3$-N and Cl in soil and groundwater occurred at plots closest to the center of depressional areas. Potential

Table 2. Mean ± standard error of the mean for nitrate levels (Kg $ha^{-1}$) in the upper root zone (0 - 0.6 m), lower root zone (0.6 - 1.2 m) and below the root zone (1.2 - 3.0 m) for control and manured treatments at all five sites. Statistical comparisons done with spring and fall values combined (n = 8) on treatments within sites using unpaired t-tests.

| | Site B | | Site C | | Site D | | Site L | | Site M | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Manured | Control | Manured | Control | Manured | Control | Manured | Control | Manured |
| Average $NO_3$-N content in 0-0.6 m depth increment (Kg $ha^{-1}$) | 27.1 ±10.1 | *497.1 ± 90.1 | 37.5 ±11.7 | *205.3 ± 33.3 | 0.35 ±0.17 | *60.8 ±20.6 | 282.3 ± 67.2 | 195.3 ±49.1 | 52.9 ±15.9 | 158.4 ±78.9 |
| Average $NO_3$-N content in 0.6-1.2 m depth increment (Kg $ha^{-1}$) | 8.2 ± 1.3 | *368.1 ±112.0 | 61.0 ±24.6 | *320.6 ± 37.4 | 0.60 ±0.13 | *74.5 ±31.0 | *243.9 ± 81.4 | 44.9 ±12.8 | 67.7 ±15.9 | 104.6 ±33.6 |
| Average $NO_3$-N content in 1.2-3.0 m depth increment (Kg $ha^{-1}$) | 20.2 ± 2.6[z] | 286.3 ± 97.2 | 115.2 ±61.6 | *463.1 ± 53.5 | 2.40 ±1.10 | 190.3 ±87.6 | *160.9 ± 26.5 | 56.0 ± 4.3 | 44.8 ±10.6[y] | 64.2 ±30.5 |

* Significant difference ($p \leq 0.05$) between treatments within site
z No statistics done on this depth increment because of uneven sampling depths between treatments
y Below root zone depth increment is 1.2 -2.1 m

Table 3. Mean ± standard error of the mean for chloride levels (ug $g^{-1}$) in the upper root zone (0 - 0.6 m), lower root zone (0.6 - 1.2 m) and below the root zone (1.2 - 3.0 m) for control and manured treatments at all five sites. Statistical comparisons done with spring and fall values combined (n = 8) on treatments within sites using unpaired t-tests.

| | Site B | | Site C | | Site D | | Site L | | Site M | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Control | Manured | Control | Manured | Control | Manured | Control | Manured | Control | Manured |
| Average Cl content in 0-0.6 m depth increment (ug $g^{-1}$) | 56.4 ± 6.6 | *434.4 ± 95.9 | 44.7 ± 8.5 | *237.5 ± 59.8 | 73.7 ±15.3 | *248.1 ± 63.5 | 30.9 ± 7.0 | *178.4 ± 29.3 | 208.7 ±54.1 | 517.5 ±162.4 |
| Average Cl content in 0.6-1.2 m depth increment (ug $g^{-1}$) | 27.2 ± 6.1 | *160.9 ± 38.2 | 20.2 ± 6.2 | *144.6 ± 21.2 | 17.4 ± 3.8 | *109.2 ± 30.2 | 7.4 ± 3.3 | 25.1 ± 8.0 | 122.2 ±35.1 | 168.6 ±53.7 |
| Average Cl content in 1.2-3.0 m depth increment (ug $g^{-1}$) | 194.8 ±36.8[z] | 145.3 ± 25.8 | 109.2 ±65.1 | 234.8 ± 14.9 | 13.9 ± 0.7 | *155.7 ± 33.3 | 15.9 ± 4.6 | *28.3 ± 3.4 | 109.1 ±36.4[y] | 139.0 ±59.2 |

* Significant difference ($p \leq 0.05$) between treatments within site
z No statistics done on this depth increment because of uneven sampling depths between treatments
y Below root zone depth increment is 1.2 -2.1 m

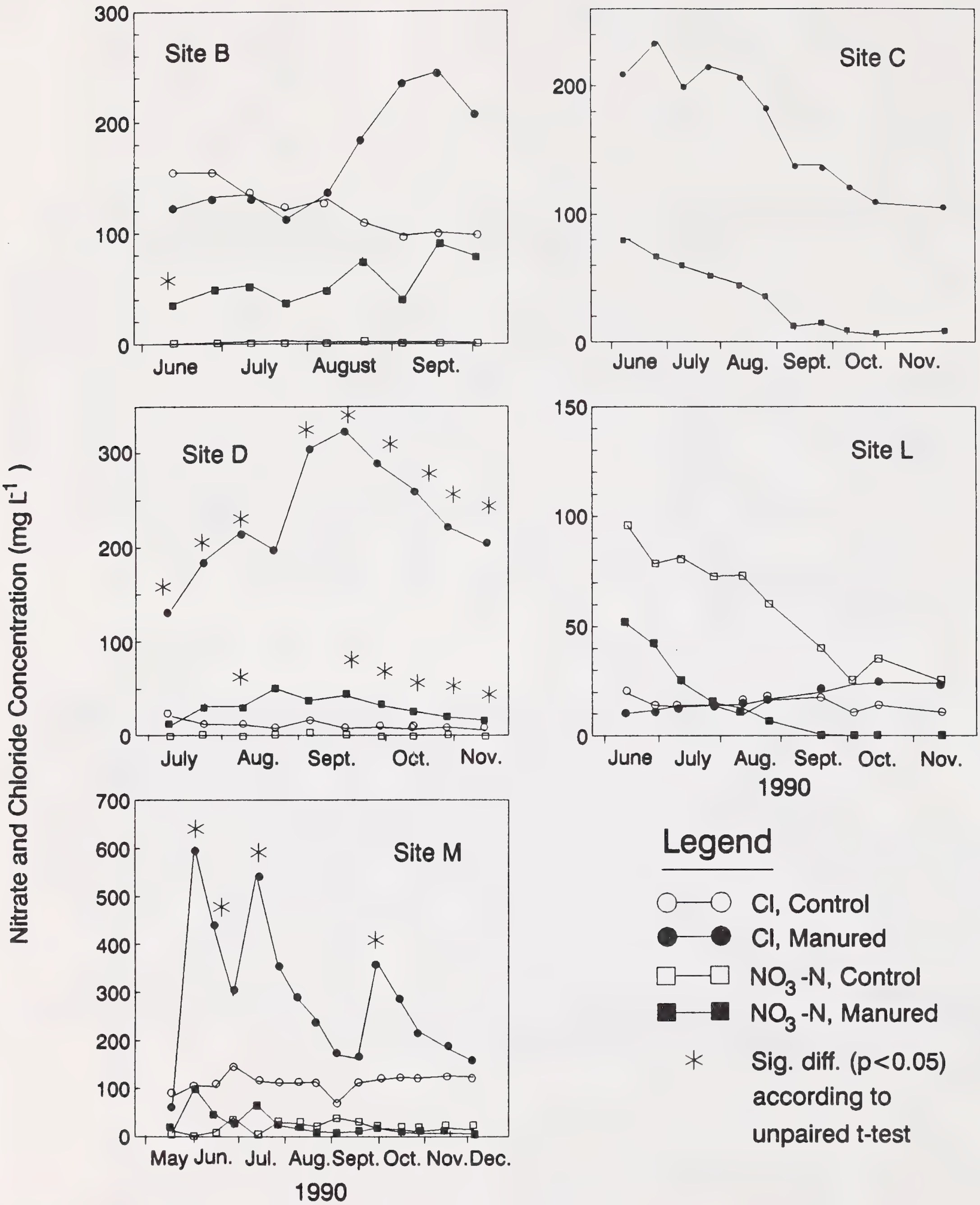


Figure 2. Changes in average nitrate and chloride concentrations (mg $L^{-1}$) in shallow groundwater with time at 5 sites. Statistical comparison is between treatments (Manured vs Control).

reasons for this trend include: 1) extra spreading of manure in depressional areas; 2) transport of $NO_3$-N and Cl via runoff into surface water collection areas; 3) groundwater flow patterns; and 4) $NO_3$-N accumulation caused by reduced crop uptake due to salinity and waterlogging.

Average Zn and $PO_4$-P levels in the surface horizons (0-15 and 15-30 cm) were higher under the manured treatment as compared to the non-manured treatments at all sites (data not shown). Soil Zn and $PO_4$-P concentrations in the 0-15 cm horizon corresponded well with the amount of manure applied at each site. The levels of DTPA extractable Zn found in the upper profile (0-30 cm) on manured land (3-10 $\mu g\ g^{-1}$) were well below levels considered toxic to plant growth (Allaway 1968). Soil Fe and Cu levels in the surface horizon (0-15 cm) were higher under the manured treatment as compared to the non-manured treatment at sites B and M (data not shown). Soil Mn levels did not differ between manured and non-manured treatments at any site (data not shown).

## CONCLUSIONS

Results of this study have documented very high levels of soil $NO_3$-N and Cl accumulating in the lower root zone and below the root zone at lower landscape positions in irrigated, manured fields at sites B, C, and D. Manure application rates and management practices varied widely between these three sites. High soil $NO_3$-N levels were also found in the lower root zone and below the root zone under the control treatment at site L. These levels were attributed to high levels of nitrogen fertilizer application during the 1980's.

$NO_3$-N levels in groundwater exceeded the drinking water limit (10 mg/L) beneath all irrigated, manured treatments and beneath the irrigated, non-manured treatment at site L. Cl levels in groundwater were much higher under the manured treatment as compared to the non-manured treatment at sites B, D, and M.

The highest levels of $NO_3$-N and Cl in soil and groundwater usually occurred at plots closest to the center of depressional areas. Contamination of deeper groundwater is possible if depression focussed recharge is occurring.

Higher levels of Zn and $PO_4$-P were found in the upper soil profile (0-30 cm) under the manured treatment as compared to the non-manured treatment at all sites. Cu and Fe levels in topsoil (0-15cm) were elevated in the manured treatment as compared to the non-manured treatment at sites B and M. There was good correlation between Zn and $PO_4$-P levels in topsoil and "best guess" estimates of the total amount of manure applied to manured treatments at all sites.

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# MONITORING OF PHENOXY-NEUTRAL HERBICIDES IN SUBSURFACE DRAIN EFFLUENT IN SOUTHERN ALBERTA

J. Rodvang & M. Riddell[1]

## ABSTRACT

Reconnaissance data were gathered on the extent to which herbicides were leached to shallow groundwater under field conditions in southern Alberta. Subsurface drain effluent samples were collected periodically at five irrigated sites. At one of the sites herbicides were also analyzed in samples collected from water-table wells and soil cores. Herbicides were detected in subsurface drain effluent and surface runoff at three of the five sites investigated. All five chemicals which were applied during the monitoring year were detected in minor amounts during irrigation, in both surface runoff and shallow groundwater. Four other herbicides were detected at sites where they were not applied during the monitoring year. All samples exhibited herbicide levels which were well below existing drinking water guidelines, with the exception of diclofop-methyl, which exceeded guidelines by a factor of about 15 at two sites. Following irrigation events, herbicides were detected in low concentrations in isolated samples of drain effluent, water-table well water and soil.

## INTRODUCTION

Specific pesticides have been found in groundwater in many areas of North America. However, very few investigations have been conducted under the field conditions encountered in southern Alberta.

Drainage effluent is shallow groundwater, but it integrates information over a much larger area than do piezometers and soil cores. Previous investigations have found that contaminant levels generally correspond to those found in other groundwater samples (Hallberg and others, 1986).

During the summer of 1991, subsurface drain effluent was monitored at five irrigated sites in southern Alberta. The purpose of the investigation was to gather reconnaissance data on the extent to which herbicides were leached to shallow groundwater under conditions typical of southern Alberta. Investigation of Sites 2 through 5 consisted of collecting drain outflow samples at appropriate times, while more detailed monitoring was conducted at Site 1.

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## METHODS OF INVESTIGATION

The five subsurface drainage sites which were selected exhibited drain outflow that was mainly the result of rainfall or irrigation, in order to minimize the effects of dilution by discharge from deeper groundwater. Sites 1 to 4 were grid drained, and Site 5 was an interceptor drain. Water-table wells were installed on May 21, 1991 at six locations on Site 1, to a depth of 3 m. The wells consisted of 1.25" I.D. slotted stainless steel pipe. Augers were pressure washed with water to remove contamination before drilling. Washed silica sand was poured around each well to a depth of 0.7 m from surface, and bentonite pellets (peltonite) formed a surface seal.

All sampling materials were washed with acetone and rinsed with deionized water before coming into contact with sample water. Water samples were collected in high density polyethylene bottles and stored in a freezer at -40°C for two to three months before analysis. Similar freezing procedures were used by Kladivko and others (1991). Preliminary investigations conducted by Hill (1991) and Bruns (1991) indicated that freezer storage did not alter herbicide concentrations. A sample of the herbicide mixture applied at Site 1 was collected from the spraying tank in the same manner, and used to determine herbicide application rate.

Water samples were collected from piezometers using either dedicated Waterra pumps or stainless steel bailers. Those collection methods were found to cause minimal loss of volatile organics during sampling (Barker and Dikhout, 1988).

Core samples to a depth of 1.2 m were collected on October 31 at each of the six water-table well locations on Site 1. Split-spoon core barrels were washed with acetone and then with deionized water before collecting each core. Samples were sectioned into 15 cm increments before being placed in double plastic bags and shipped to the analyzing laboratory on the same day.

Organic analysis of water and soil samples was done using a Gas Chromatograph/Mass Spectrometer combination (Rodvang and Riddell, 1992). Inorganic ions were analyzed using standard methods.

## RESULTS

### Site 1

Site 1 was ideal for detailed monitoring because the outlet collected water only from a single field, since surrounding fields had their own drainage systems. The number of variables was also reduced because the only chemical applied over the last six years was 2,4-D, and the only crop grown was barley. In 1991 the farmer switched from 2,4-D to Hoe-Grass II.

Parent material at Site 1 consisted of sandy clay loam lacustrine material to a depth of 1.5 to 2 m, with discontinuous sand over till at 2 m. Water levels fluctuated between about 1 and 2 m. Hoe-Grass II was applied on May 27, 1991. The chemical application rate, calculated from the measured concentration in the tank mix, was 677 g/ha diclofop-methyl and 3.6 g/ha bromoxynil. Triallate was also detected, at 5.8 g/ha. The triallate may have been a contaminant remaining in the spraying tank from a previous occasion.

Site 1 received approximately 5.2 mm of rain between spraying and the single irrigation event. This rain caused flow in the drain outlet to increase from 0.03 to 0.14 L/s on May 28. Irrigation took place between June 3 and June 10, using a side-wheel roll system. Approximately 100 mm of irrigation water was applied, which caused the flow in the drain outlet to increase from 0.03 to 1.54 L/s during irrigation. Samples were collected before herbicide application, daily during the irrigation event, and several times after irrigation stopped, with the last sample collected on October 31.

A minor amount of 2,4-D was detected in the drain effluent following the rain on May 28. Traces of 2,4-D were detected in drain samples during the first 9.5 h following the beginning of irrigation, and in water-table wells during the first four days of irrigation. It is probable that the 2,4-D was residual from previous years.

Diclofop-methyl first appeared in the drain effluent 9.5 h after the beginning of irrigation at 3.4 $\mu$g/L and in a water-table well 8 h after the beginning of irrigation over the top of the well. Thereafter, lesser concentrations of diclofop-methyl were detected in several samples during the irrigation event. Diclofop methyl was not detected in drain effluent following the end of irrigation. However, it occurred at 130 $\mu$g/L in the north-east well on June 10, thus exceeding Canadian Drinking Water guidelines by a factor of about 15. It was not detected again until October 31, when it occurred at 0.17 $\mu$g/L in the south-west well. Diclofop-methyl was also detected at 45 $\mu$g/L in a sample of surface runoff from an adjacent field.

Bromoxynil was detected at less than 1 $\mu$g/L in drain effluent, water tables, and surface runoff. It had disappeared from all samples three days after the end of irrigation.

Small amounts of mecoprop, dicamba and MCPA (up to 1, 0.83, and 12 $\mu$g/L, respectively) were detected in several samples of drain effluent and water-table well water at Site 1 even though they have not been applied for at least six years. They may have been transported to the sites via wind, surface runoff, or groundwater. This hypothesis is supported by the analysis of a surface runoff sample collected from a field immediately south of site 1. That sample contained the latter three chemicals, in addition to diclofop-methyl and bromoxynil.

Herbicides were detected in at least one sample from all water-table wells. However, the highest concentrations generally occurred in the south-west well. This may be because drainage over most of the field was towards the south-west corner, or because the south-west well was only 2 m deep, in contrast to the other wells, which were 3 m deep. In other words, most of the herbicides would be in the shallowest groundwater. The north-east well, which contained the high hit of diclofop-methyl, was located in an isolated topographic depression.

Herbicides were detected in only three soil samples. Diclofop-methyl was detected in the surface sample at two locations, at up to 9.5 $\mu$g/L. Triallate was detected in one 45 to 60 cm sample in one location.

With the notable exception of diclofop-methyl in the north-east well and surface runoff, all herbicides occurred at levels well below existing Canadian Drinking Water Guidelines (CCREM, 1987; Health & Welfare Canada, 1987).

Site 2

The parent material at Site 2 was clay loam till to a depth of at least 3 m. Barley was seeded over the drained area in the north half of the field on May 2 and 3, and sugar beets were seeded just south of the drained area on April 23. Avadex BW (active ingredient Triallate) was applied to the barley and beets during seeding. Fifty-one mm of irrigation water were applied using a side-wheel roll between June 10 and June 20, when the site received 101.6 mm of rain. Flow in the drain outlet increased from 0.03 to 1.45 L/s during irrigation. Samples were collected two, four and seven days into the irrigation event, as well as before and after irrigation.

Triallate was detected only at trace levels in a surface runoff sample collected on the seventh day of irrigation. Small amounts of MCPA, dicamba and mecoprop, at concentrations up to 5.4, 1.5, and 1.6 $\mu$g/L, respectively, were detected in all samples of drain effluent and surface runoff, even though none of these chemicals were applied during 1991. No herbicides were detected before or following the irrigation event.

Site 3

Site 3 consisted of silty clay loam to clay lacustrine material to depths of at least 5 m. Irrigation with a side-wheel roll occurred between July 6 and July 14. Samples were collected daily during the irrigation event, with the first sample collected eight hours after the beginning of irrigation. At that time the drain had increased from zero-flow to its maximum level of 4 L/s.

Applied herbicides (bromoxynil and MCPA, in the form of Buctril M) were not detected in any of the drain water samples, nor were traces of any other herbicides detected. The maximum flow was almost four times higher at this site than at Sites 1 and 2. If herbicides were present, this high flow rate may have caused dilution to levels below detection.

Site 4

Soils at Site 4 were lacustrine material of fine sandy loam texture, over clay loam till at depths of 1 to 2.5 m. Irrigation was with a centre-pivot system. The site received 70 mm of irrigation plus rain water between June 19 and June 22, and 63.5 mm of irrigation between July 13 and July 20. Samples were collected once during each irrigation, and before and after both irrigation events. Triumph Plus (active ingredient MCPA) and Hoe-Grass II (active ingredients bromoxynil and diclofop-methyl) were applied but not detected in any of the drain water samples, nor were traces of any other herbicides detected.

There is generally less recharge under irrigation using a centre-pivot than using side-wheel rolls or corrugation. In addition, the drain at Site 4 had a substantial contribution from groundwater. Therefore, the lack of detectable herbicides at this site may be related to an absence of a significant irrigation return flow component in the drain effluent. It is also possible that herbicides may have been detected under a more rigorous sampling program.

Site 5-West (Interceptor)

Site 5-West has been under wheat and beets since 1974. Hoe-Grass II (active ingredients diclofop-methyl and bromoxynil) was applied to the wheat on May 13. The first drain sample, collected on May 14, contained 137 μg/L diclofop-methyl and 0.79 μg/L bromoxynil. The site received over 152 mm of rain between mid-May and mid-June, and a sample collected on July 3 did not contain detectable herbicides. MCPA, dicamba and mecoprop, in the form of Target, were applied to the wheat on June 1. The site was irrigated between July 17 and July 27, using corrugation (a type of flood irrigation). Samples of surface runoff and drain effluent collected five days into the irrigation event contained traces of the latter three chemicals.

## DISCUSSION

Less than 1% of the diclofop-methyl applied at Site 1 was recovered in drain effluent, assuming that the total amount coming off the field can be interpolated from collected samples. This recovery rate is similar to that found for other herbicides in New Brunswick (O'Neill and others, 1990) and Indiana (Kladivko and others, 1991).

Some absorption of herbicides is expected to occur on the plastic which composes the subsurface drain tiles (Reynolds and others, 1989). This effect is likely to contribute to the appearance of residual herbicides in drain effluent, due to slow desorption over time. However, at Site 1 herbicide types and concentrations were comparable between stainless steel water-table wells and drain effluent. Drain effluent integrates shallow groundwater over a large area, while water-table wells sample at a point, so the high concentrations of diclofop-methyl in isolated water-table-well samples may be explained by natural site variability. The appearance of herbicides within hours of the beginning of irrigation indicates that fracture flow is important in contaminant transport at these sites, similar to the findings of Kladivko and others (1991).

## SUMMARY OF RESULTS

Herbicide concentrations were comparable between drain effluent, water-table wells and surface runoff, although surface runoff tended to exhibit slightly higher herbicide levels. Low concentrations of herbicides were detected in subsurface drain effluent at three out of the five sites investigated. At Site 3 herbicides may have been diluted below detection by high flow rates in the drain. At Site 4 the samples may not have had a substantial return flow component.

Minor amounts of all five of the herbicides that were applied during the monitoring year were detected, although many other samples did not contain detectable herbicides. Applied and detected herbicides included diclofop-methyl, bromoxynil, dicamba, MCPA and triallate, although triallate was detected only at very low concentrations in isolated samples. Triallate has a low water solubility, which may explain its apparent lack of mobility.

Minor amounts of herbicides which were not applied during the monitoring year were detected at Sites 1, 2 and 5. These included dicamba, mecoprop, MCPA and 2,4-D. The latter chemicals are highly soluble in water, which may account for their mobility.

The highest herbicide concentrations tended to be detected at the beginning of irrigation events, with decreasing levels over time. Very few samples exhibited detectable herbicides following the end of irrigation. At Site 1, minor amounts of diclofop-methyl and 2,4-D were detected in two samples from water-table wells and two surface soil samples five months after irrigation. Maximum detected herbicide levels were well below existing Canadian Drinking Water Guidelines, with the exception of diclofop-methyl at Sites 1 and 5, where it exceeded the guidelines in isolated samples by factors of up to 14 and 15, respectively (CCREM, 1987; Health & Welfare Canada, 1987).

## RECOMMENDATIONS FOR FUTURE WORK

The current investigation has documented the movement of herbicides below the root zone under some irrigated drained field conditions in southern Alberta. Further investigation is warranted in the following areas.

1) Tile effluent is not used directly as drinking water. However, drain effluent eventually discharges into river and canal systems, which are often used as drinking water. The effect of drain effluent on receiving surface water bodies should be investigated.
2) The movement of herbicides below the root zone poses the potential for contamination of deeper aquifers. The fate of herbicides deeper in the saturated zone should be investigated.
3) There is a need to study the water quality effects of different crops, soil types, management practices, and herbicide types.

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# WATER QUALITY IN SELECTED RETURN-FLOW CHANNELS

T. Bolseng[1]

## INTRODUCTION

On average, 29% of the total volume of water diverted for irrigation in Alberta reappears as return flow (Barnetson 1985). Irrigation-return flows are of sufficient volume that degradation in water quality can have an impact on receiving streams. Previous studies monitoring water quality in return-flow channels have shown mixed evidence. Oosterveld et al. (1978) found the quality of irrigation-return flow was similar to the original water supply, with only a slight increase in salinity. Hamilton et al. (1982) demonstrated that some irrigation-return flow has high salt concentrations, which suggests salt loading from surface water or groundwater sources. This same study, however, concluded that irrigation-return flow has not significantly impacted on water quality in the South Saskatchewan River Basin.

In order to assess if return flows have undergone degradation, the Land Evaluation and Reclamation Branch in cooperation with the Irrigation Branch has compiled a preliminary database on water quality in selected return-flow channels.

## METHODS

Between June 1990 and August 1991, water samples were collected by the Irrigation Branch at 38 return-flow channels located within the Bow River (BRID), Lethbridge Northern (LNID), Raymond (RID), St. Mary River (SMRID), Taber (TID) and United (UID) irrigation districts (Fig. 1). Sampling was limited to one date per return-flow channel. The water samples were analyzed for pH, electrical conductivity (EC), sodium adsorption ratio (SAR), cations (calcium (Ca), magnesium (Mg), sodium (Na), potassium (K)), anions (sulfate ($SO_4$), carbonate ($CO_3$), bicarbonate ($HCO_3$), chloride (Cl)) and nitrate ($NO_3$-N)) using standard analytical techniques (American Public Health Association 1989).

## RESULTS AND DISCUSSION

The mean EC and SAR levels of 38 return-flow channel water samples collected from across six irrigation districts ranged from 0.23 to 1.02 dS/m and 0.2 to 2.2, respectively (Table 1). With the exception of one water sample from the RID, all samples were of good quality and met established guidelines for human (CCREM 1987) and livestock (Alberta

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FIG 1. RETURN–FLOW CHANNEL SAMPLING LOCATIONS (•)

Agriculture 1987) consumption as well as irrigation guidelines (Alberta Agriculture 1983). The high EC of 2.32 dS/m indicated salt loading occurred along a portion of the RID distribution system. There was no perceptible flow in the RID return-flow channel at the time of sampling which could account for the observed poor water quality.

McMullin et al. (1984) and Matis (1989) found an inverse relationship between flow and water quality in the Stirling Drain in the RID where salt loading also occurs. During the irrigation season, when spill water from the RID is released down the Stirling Drain, the EC and SAR decline with the increase in flow. The water quality improved as a result of dilution and was within the recommended limits for all potential uses. When no water was spilled from the RID, the water quality worsened with the decline in flow.

Comparison of mean EC, SAR and $NO_3$-N levels between water entering (Table 2) and leaving (Table 1) the BRID, LNID and TID distribution networks revealed little or no change, suggesting no degradation in water quality.

The average $NO_3$-N levels in all return flow channels were low, ranged from < 0.1 to 0.25 mg/L, and within the 10 mg/L limit recommended for human consumption of water (CCREM 1987).

Table 1. Means ± standard deviations for EC, SAR and $NO_3$-N for return-flow channels sampled in six irrigation districts in 1990 and 1991

| Irrigation District | n | EC (dS/m) | SAR | $NO_3$-N (mg/L) |
|---|---|---|---|---|
| BRID | 3 | 0.37 ± 0.00 | 0.6 ± 0.0 | 0.14 ± 0.00 |
| LNID | 9 | 0.32 ± 0.03 | 0.1 ± 0.1 | 0.12 ± 0.13 |
| RID | 3 | 1.02 ± 1.13 | 2.2 ± 2.1 | 0.00 ± 0.00 |
| SMRID | 5 | 0.23 ± 0.02 | 0.3 ± 0.0 | 0.11 ± 0.25 |
| TID | 16 | 0.36 ± 0.12 | 0.7 ± 0.4 | 0.02 ± 0.06 |
| UID | 2 | 0.24 ± 0.02 | 0.3 ± 0.1 | 0.00 ± 0.00 |

Table 2 Means ± standard deviations for EC, SAR and $NO_3$-N for water samples collected from canals in three irrigation districts in 1990 and 1991

| Irrigation District | Canal | EC (dS/m) | SAR | $NO_3$-N (mg/L) |
|---|---|---|---|---|
| BRID[z] | Lateral E#2 | 0.34 ± 0.01 | 0.6 ± 0.0 | 0.00 ± 0.00 |
| LNID[y] | Monarch Main Canal (MMC) | 0.29 ± 0.04 | 0.2 ± 0.00 | 0.00 ± 0.00 |
| TID[y] | Big Bend Main Canal (BBMC) | 0.38 ± 0.09 | 1.1 ± 0.2 | 0.00 ± 0.00 |

[z] Alberta Agriculture, unpublished data
[y] Bolseng (1991 and 1992)

## CONCLUSIONS

The strictest limits for water quality are for human consumption. The water quality of the 38 return-flow channels sampled within six irrigation districts, with the exception of one sample from the RID, was within those recommended limits. This information must be interpreted with caution as the "one time only" nature of the sampling does not reflect the potential fluctuations with can occur in the quantity and quality of return flow. Flow levels and water quality in the return-flow channels can be influenced by rainfall patterns, runoff, irrigation practices, seepage losses and groundwater discharge. Continuous or "event orientated" monitoring of water quality in return-flow channels is recommended.

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# WATER QUALITY IN IRRIGATION-DISTRIBUTION SYSTEMS

T. Bolseng[1]

## INTRODUCTION

The total amount of water diverted to irrigation districts in Alberta has increased 62%, from 1,661,000 $dam^3$ * in 1972 to 2,639,000 $dam^3$ in 1984. Concurrently, there has been a decrease in irrigation-return flow from 33% (548,000 $dam^3$) in 1972 to 21% (545,000 $dam^3$) in 1984 (Barnetson 1985). Reductions in the percentage of return flow are attributed to an increase in irrigated acres, rehabilitation of irrigation-distribution systems and a significant changeover from gravity-feed to sprinkler irrigation, thus making more efficient use of irrigation water (Environment Canada 1985).

Irrigation-return flows are of sufficient volume that any degradation in water quality in the irrigation-distribution system can have an impact on receiving streams. Oosterveld et al. (1978) found the quality of irrigation-return flow is similar to the original water supply, with only a slight increase in salinity. Hamilton et al. (1982) demonstrated that some irrigation-return flow has high salt concentrations, which suggests salt loading from surface water or groundwater sources. This same study, however, concluded that irrigation-return flow has not significantly impacted on water quality in the South Saskatchewan River Basin.

In addition to salts, other potential contaminants of concern include nitrates, trace elements, and pesticides. Potential sources for these contaminants include subsurface drainage effluent, surface runoff, groundwater and application of agricultural chemicals or by-products such as manure.

Water conveyed in irrigation-distribution systems is not used solely for irrigation. Conveyed water is also used for domestic, municipal, livestock, industrial and wildlife purposes and must meet established guidelines for human (CCREM 1987) and livestock (Alberta Agriculture 1987) consumption in addition to irrigation guidelines (Alberta Agriculture 1983).

In order to assess if irrigation water is undergoing degradation, the Land Evaluation and Reclamation Branch has begun to compile a database on water quality in irrigation-distribution systems. This report describes results of monitoring conducted in Lethbridge Northern (LNID) and Taber (TID) irrigation districts for the 1990 and 1991 irrigation seasons.

* $dam^3$ = 1000 metres cubed

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## METHODS

With the exception of some main irrigation canals, flow monitoring and sample collection were based on a two year rotation. The data in this report comes from 14 water quality sampling locations in the LNID and TID (Figures 1 and 2). Water quality samples were taken by Irrigation Branch personnel on a biweekly basis during the 1990 and 1991 irrigation seasons. Most sample locations were paired along the upper and lower reaches of laterals. Water samples were analyzed for pH, electrical conductivity (EC), sodium adsorption ratio (SAR), standard cations (calcium (Ca), magnesium (Mg), sodium (Na), potassium (K)) and anions (sulfate ($SO_4$), carbonate ($CO_3$), bicarbonate ($HCO_3$), chloride (Cl)) and nitrate ($NO_3$-N) using standard analytical techniques (American Public Health Association 1989). Three samples in 1990 and four samples in 1991 from each station were analyzed for the trace elements arsenic (As), cadmium (Cd), iron (Fe), lead (Pb), manganese (Mn), molybdenum (Mo) and selenium (Se) using atomic absorption spectrometry.

## RESULTS AND DISCUSSION

### LNID

The average EC for all LNID stations was slightly higher in 1990 than in 1991 (Table 1). In 1990, Lateral C12 #1 had the highest mean EC, SAR and standard deviations due to a single sample taken early in the sampling year (June 1990) (Table 1). The mean EC and SAR values of head and tail stations remained constant within the individual systems and vary slightly between the two systems and sampling years. Complete water chemistry data will be available in a separate report being prepared.

Table 1. Means $\pm$ standard deviations for EC and SAR for LNID stations sampled during 1990 and 1991

| | 1990 | | 1991 | |
|---|---|---|---|---|
| Lateral # | EC(dS/m) | SAR | EC(dS/m) | SAR |
| C12 #1 (head) | 0.35±0.24 | 0.41±0.30 | 0.26±0.04 | 0.37±0.07 |
| C12 #2 (tail) | 0.32±0.07 | 0.34±0.14 | 0.29±0.04 | 0.36±0.05 |
| C12 A (tail) | 0.28±0.04 | 0.31±0.07 | 0.26±0.04 | 0.36±0.07 |
| DICI #1 (head) | 0.27±0.05 | 0.36±0.10 | 0.24±0.05 | 0.38±0.06 |
| DICI #2 (tail) | 0.28±0.05 | 0.36±0.07 | 0.25±0.04 | 0.37±0.09 |
| DICI B (tail) | 0.27±0.04 | 0.36±0.07 | 0.25±0.05 | 0.37±0.09 |

### TID

Mean EC and SAR levels were higher for the Big Bend Main Canal (BBMC) system than for the Lateral 3 and 20 system (Table 2). The BBMC system is located downstream of the Taber Lake Reservoir. The higher average EC and SAR values could be attributed to changes occurring in the reservoir caused by evaporation and aquatic plant growth. Mean EC and SAR within both systems remained constant for both sampling years.

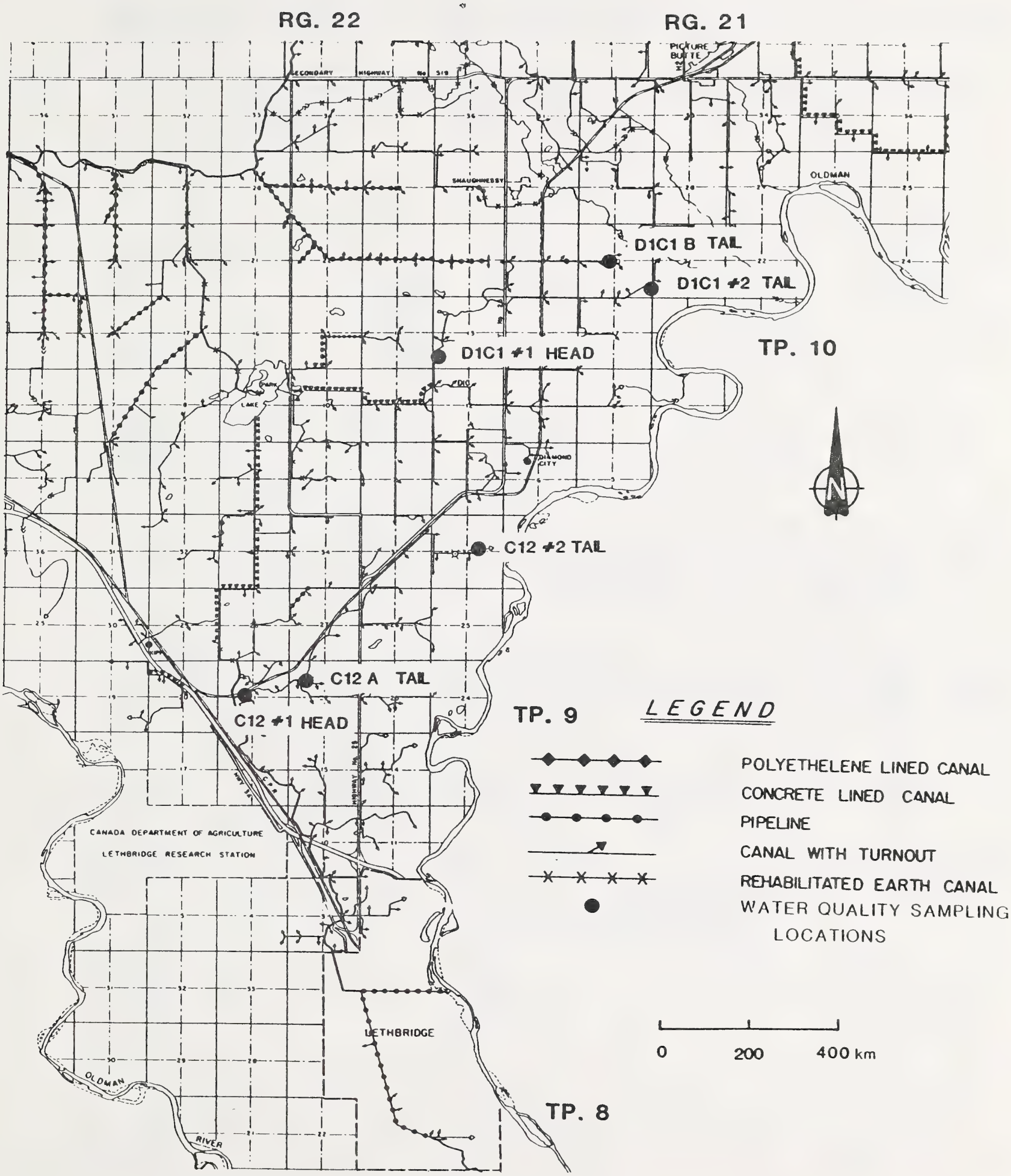


**Figure 1.** **Water quality sampling locations in LNID during the 1990 and 1991 irrigation seasons**

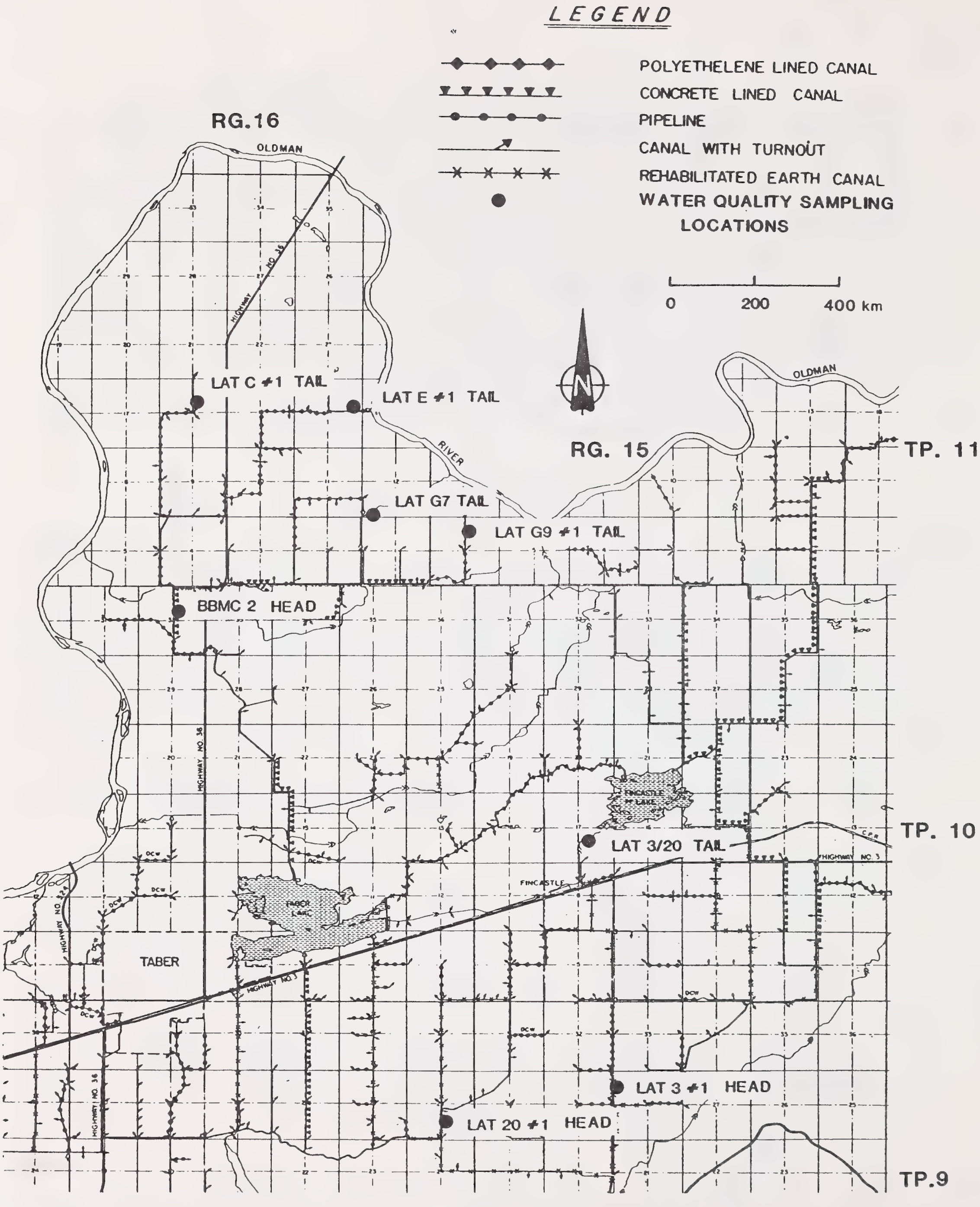


**Figure 2. Water quality sampling locations in TID during the 1990 and 1991 irrigation seasons**

Complete water chemistry will be available in a separate report being prepared.

Table 2. Means ± standard deviations for EC and SAR for TID stations sampled during 1990 and 1991

| | 1990 | | 1991 | |
|---|---|---|---|---|
| Lateral # | EC(dS/m) | SAR | EC(dS/m) | SAR |
| BBMC #2 (head) | 0.38±0.09 | 1.11±0.22 | 0.38±0.05 | 1.13±0.14 |
| C #1 (tail) | 0.35±0.08 | 1.09±0.17 | 0.38±0.06 | 1.14±0.14 |
| E #1 (tail) | 0.38±0.09 | 1.11±0.20 | 0.38±0.05 | 1.11±0.12 |
| G7 (tail) | 0.44±0.11 | 1.22±0.22 | 0.46±0.11 | 1.31±0.22 |
| G9 #1 (tail) | 0.40±0.10 | 1.16±0.24 | 0.38±0.04 | 1.22±0.11 |
| 3 #1 (head) | 0.27±0.03 | 0.40±0.09 | 0.26±0.01 | 0.42±0.04 |
| 20 #1 (head) | 0.27±0.03 | 0.38±0.07 | 0.27±0.03 | 0.47±0.11 |
| 3/20 (tail) | 0.28±0.04 | 0.44±0.13 | 0.31±0.11 | 0.52±0.21 |

For all LNID and TID stations monitored during 1990 and 1991 $NO_3$-N levels were low, ranging from < 0.1 to 0.3 mg/l, and well within the 10 mg/l limit recommended for human consumption of water (CCREM 1987).

<u>Trace Elements</u>

Most of the trace element results were below the detection limits (Table 3). All results were within the recommended limits for human, livestock and irrigation use of water as set out by the various water quality guidelines.

Table 3. Trace element results for water quality sampling stations in the LNID and TID during 1990 and 1991

| Element | Result (mg/l) | Recommended Maximum Limit$^{z}$ (mg/l) |
|---|---|---|
| As | < 0.0003$^{x}$ - 0.003 | 0.05 |
| Cd | < 0.03$^{x}$ | 0.005 |
| Fe | < 0.10$^{x}$ | 0.3 |
| Pb | < 0.03$^{x}$ | 0.05 |
| Mn | < 0.03$^{x}$ - 0.03 | 0.05 |
| Mo | < 0.10$^{x}$ - 0.18 | 0.5$^{y}$ |
| Se | < 0.001$^{x}$ - 0.002 | 0.01 |

$^{z}$ Canadian Water Quality Guidelines (1987)
$^{y}$ USSR Water Quality Limit (1970)
$^{x}$ Detection limit

## CONCLUSIONS

From the data collected during 1990 and 1991 there appears to be no significant degradation in the water quality in irrigation-distribution

systems monitored in the LNID and TID. The strictest limits for water quality are for human consumption. The water quality was within those recommended limits. The data will be used as baseline information for future investigations into irrigation-water quality.

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# IMPACT OF SUBSURFACE TUBE DRAINAGE EFFLUENT ON SALT AND NITRATE LEVELS IN THE MONARCH DRAIN

T. Bolseng[1]

## INTRODUCTION

Shallow subsurface tube drainage has been installed on approximately 3000 hectares of irrigated land in Alberta (Alberta Agriculture 1987). Artificial drainage removes excess water and provides suitable growing conditions for crop growth by collecting and discharging effluent into natural and man-made open drains. Drain effluent contains soluble salts and nutrients leached from the soil and this has raised concerns of its possible negative impact on water quality of receiving streams.

In order to assess the impact of salt and nitrate ($NO_3$-N) loading from subsurface tube drainage effluent on surface water quality in the Monarch drain, the Land Evaluation and Reclamation Branch has monitored flow and water quality of drain effluent and surface water along the Monarch drain.

## METHODS

The Monarch spill drain is located in the Lethbridge Northern Irrigation District (LNID) (Figure 1). It collects and returns groundwater seepage, surface runoff, tube drainage effluent and irrigation spill water to the Oldman River. There are 16 subsurface tube drainage outlets and one deep interceptor drain that can discharge into the drain. The LNID diverts irrigation water from the Monarch Main Canal (MMC) to supply irrigation systems located along the Monarch drain.

From May to November, 1990 tube drainage effluent, deep interceptor and open drain water samples, as well as flow measurements were collected monthly from the Monarch drain system. A cipolletti weir erected at the lower reach of the drain measured return (tail) flow to the Oldman River. A graduated bucket and stop watch were used to measure the tube drainage and deep interceptor flows. The water samples were analyzed for pH, electrical conductivity (EC), sodium adsorption ratio (SAR), cations (calcium (Ca), magnesium (Mg), sodium (Na), potassium (K)), anions (sulphate ($SO_4$), carbonate ($CO_3$), bicarbonate ($HCO_3$), chloride (Cl)) and $NO_3$-N using standard analytical techniques (American Public Health Association 1989). The total dissolved solids (TDS) value was the cumulative ion total.

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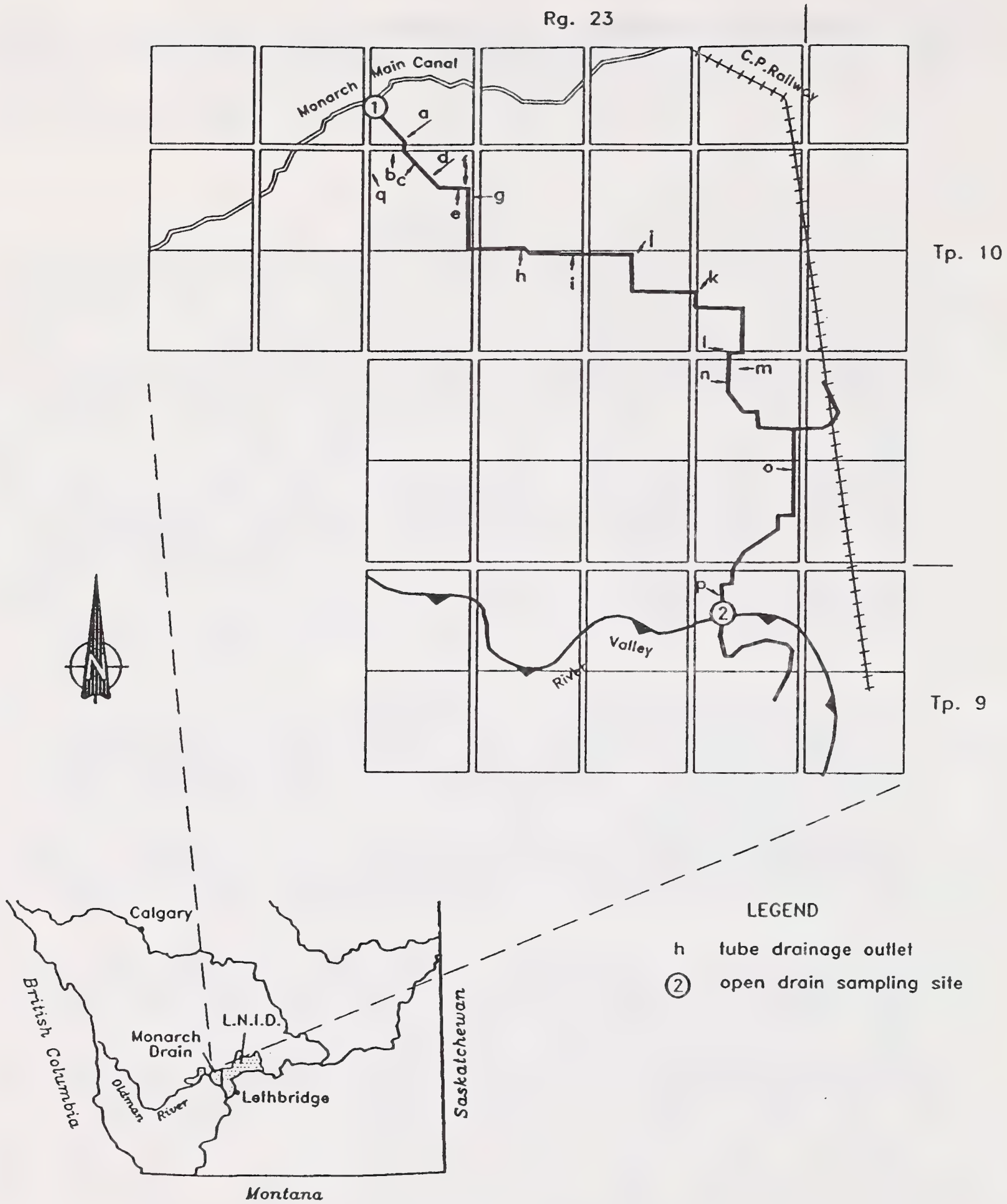


Figure 1. Monarch Drain location map

## RESULTS AND DISCUSSION

During the eight-month sampling season, 50% or more of the 16 tube drainage outlets were flowing and discharging effluent into the Monarch drain. The cumulative outlet flows ranged from 0.9 to 9.4 liters per second (L/s) and from 0.5% to 11.4% of the return flow to the Oldman River as measured at the weir (Table 1). An identical flow of 0.9 L/s was 11.4% of return flow on May 7th and 0.5% of return flow on September 25th. On June 28th, a ten-fold increase in outlet flow to 9.4 L/s was only 2.8% of return flow. The high discharge months for the tube drainage outlets corresponded with the high surface water flow in the Monarch drain, thus minimizing the impact of the effluent on water quality in the drain.

Table 1. Flow (L/s) for tube drainage outlets, deep interceptor drain and return flow at the weir on lower end of Monarch drain and % of return flow for the outlets and deep interceptor drain during 1990

| Date (1990) | Return Flow L/s | Cumulative Outlet Flow L/s | Cumulative Outlet Flow % of Return Flow | Deep Interceptor Flow L/s | Deep Interceptor Flow % Return Flow |
|---|---|---|---|---|---|
| May 7 | 7.9 | 0.9 | 11.4 | 0.8 | 10.5 |
| June 6 | 133.7 | 7.1 | 5.3 | 1.3 | 1.0 |
| June 28 | 330.2 | 9.4 | 2.8 | 1.3 | 0.4 |
| July 30 | 175.6 | 5.8 | 3.3 | 1.2 | 0.7 |
| Aug 28 | 101.3 | 1.5 | 1.5 | 1.0 | 1.0 |
| Sept 25 | 175.6 | 0.9 | 0.5 | 1.0 | 0.5 |
| Oct 25 | 17.0 | 1.0 | 5.8 | 1.0 | 5.9 |
| Nov 27 | --- | 0.3 | --- | 0.8 | --- |

The deep interceptor drain flows varied 0.5 L/s throughout the sampling season (Table 1). It's contribution to the return flow ranged from 0.4% on June 29th to 10.5% on May 7th.

Salt flux (kilograms per second (kg/s)) was TDS (kg/L) x flow (L/s). The cumulative outlet salt flux ranged from 3.1 to 45.8 kg/s and was 12.3% to 54.1% of the return flow salt flux (Table 2). The largest salt flux contribution of 45.8 kg/s on June 6th was 50.7% of the return flow salt flux. The impact of the cumulative outlet salt flux is minimized by the large surface water flow in the Monarch drain that occurs at the same time.

The deep interceptor drain salt flux contribution varied from 2.6 to 5.1 kg/s and was 4.2% to 15.4% of the return flow salt flux (Table 2).

Table 2. Salt flux (kg/s) for the tube drainage outlets, deep interceptor drain and return flow at the weir on the lower end of the Monarch drain and % of return flow salt flux for the outlets and deep interceptor drain during 1990

| Date | Return Flow kg/s | Cumulative Outlet kg/s | Cumulative Outlet % of Return Flow Salt Flux | Deep Interceptor Drain kg/s | Deep Interceptor Drain % of Return Flow Salt Flux |
|---|---|---|---|---|---|
| May 7 | 26.8 | 7.2 | 26.8 | 3.0 | 11.0 |
| June 6 | 90.3 | 45.8 | 50.7 | 5.1 | 5.6 |
| June 28 | 72.5 | 39.2 | 54.1 | 4.9 | 6.7 |
| July 30 | 96.6 | 33.9 | 35.1 | 4.1 | 4.2 |
| Aug 28 | 25.3 | 5.0 | 19.9 | 3.2 | 12.7 |
| Sept 25 | 41.6 | 5.1 | 12.3 | 2.5 | 6.0 |
| Oct 25 | 20.9 | 5.5 | 26.1 | 3.2 | 15.4 |
| Nov 27 | ---- | 3.1 | ---- | 2.6 | ---- |

The range, median and mean of $NO_3$-N concentrations in samples from the outlets, deep interceptor drain and Monarch drain return flow at the weir is given in Table 3. Cumulative outlet $NO_3$-N levels range from 0.0 to 203 mg/L with a median of 2.7 mg/L and a mean of 20.6 mg/L. When data contains extremely large or small values (as in the outlet $NO_3$-N values), the median can provide a more accurate measure of the central tendency than the mean. The deep interceptor drain $NO_3$-N levels varied from 9.4 to 14.6 mg/L with a mean of 12.0 mg/L and a median of 11.6 mg/L. $NO_3$-N levels found in moving surface waters at the tail end of Monarch drain ranged from 0.0 to 1.3 mg/L (Table 3). These levels were within the 10 mg/L of $NO_3$-N limit recommended for human consumption of water (CCREM 1987).

Table 3. Range, median, mean of $NO_3$-N (mg/L) for tube drainage outlets, deep interceptor drain and return flow at the weir along the Monarch drain in 1990

| Source | Range | Median | Mean |
|---|---|---|---|
| Cumulative outlet | 0.0 - 203.2 | 2.7 | 20.6 |
| Deep interceptor drain | 9.4 - 14.6 | 11.6 | 12.0 |
| Return flow at weir on lower end of Monarch drain | 0.0 - 1.3 | 0.2 | 0.4 |

## CONCLUSIONS

The impact of drain effluent from 16 tube drainage outlets and one deep interceptor drain on flow, salt flux and $NO_3$-N concentrations in the Monarch drain appeared to be minimal. The strictest TDS and $NO_3$-N limits for water quality are for human consumption. The return flow water quality at the weir at the end of the Monarch drain was within those limits during the irrigation season (June to September) and

always met the limits recommended for livestock and irrigation use (Alberta Agriculture 1987 and 1983).

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# VERDIGRIS LAKE WATER QUALITY - 1991

G. Cook[1], J. Ganesh[2], L. Kwasny[1]

## INTRODUCTION

Irrigation water quality in Verdigris Lake has been monitored by numerous parties since 1983. Water users and the irrigation district have always been concerned that the electrical conductivity (EC) and sodium adsorption ratio (SAR) have exceeded the safe limits for irrigation. Unfortunately, management of the reservoir to minimize salt loading has been difficult, mainly due to inadequate flow monitoring and variable irrigation demands.

After several years of steady improvement, water quality in the lake deteriorated above safe levels throughout the summer of 1989 and 1990. In 1991, quality has improved substantially. The flow monitoring carried out by the hydrometric unit of the irrigation branch, coupled with the water sampling and irrigation monitoring of the irrigation branch office in Taber for 1991 are presented in this report. A water and salt balance for the reservoir has been calculated for the 1991 irrigation season.

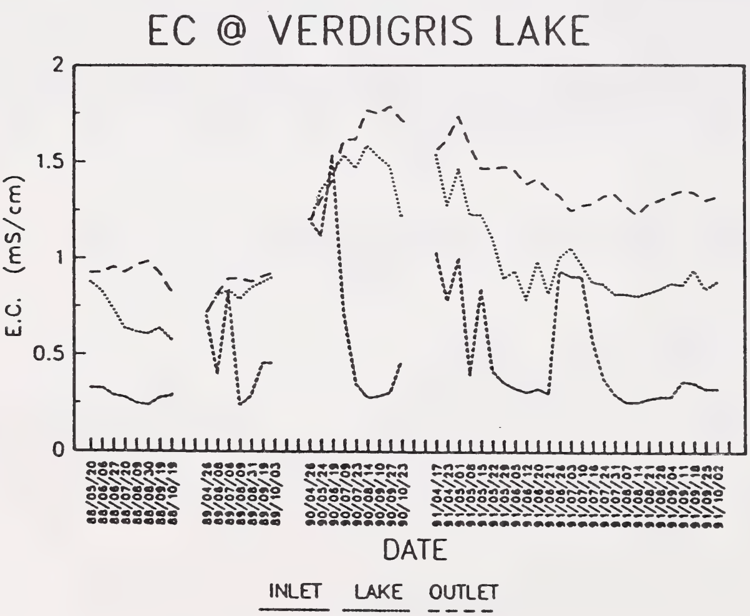


FIGURE 1

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## METHOD

### Water Balance

The hydrometric unit of Alberta Agriculture installed three flow monitoring stations. The first was at the top end of Middle Coulee. The second was at a structure immediately upstream of Verdigris Lake near highway #504. The third station was at a drop structure immediately downstream of Verdigris Lake. Throughout the season, these stations provided inflow and outflow volumes for the system. Alberta Environment maintains a Water Survey of Canada flow measuring station on Hummel's Coulee. Preliminary information for the flows through this station, located approximately 2 kilometers from the lake, have been used to more accurately reflect the effects of a major storm occurring on June 21, 1991.

Evaporation and precipitation rates were determined at a location on the downstream end of the lake. Evaporation was determined using a Class A pan. Pan evaporation rates were converted to lake evaporation rates using the formula:

Lake Evaporation = (Pan Evaporation + 5.74) / 1.69

This formula is based on a comparison of several years of shallow lake evaporation estimates provided by Alberta Environment and Class A pan evaporation data for Lethbridge. The lake evaporation coupled with rainfall is represented throughout this report as a surface loss. In two weekly periods this is a negative number, meaning that rainfall for the week exceeded evaporation.

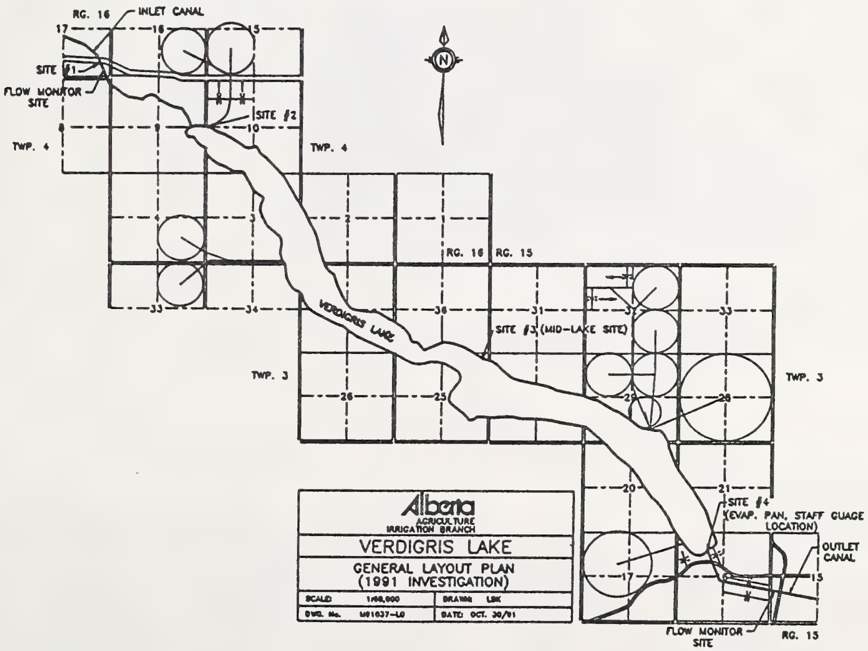


FIGURE 2

2297 acres of land are irrigated from pump stations located between the second and third flow monitoring stations. Hours of operation for these pumping units were tallied on a weekly basis to determine irrigation withdrawals from Verdigris Lake. Pumping rates were determined from flow tests and design specifications.

Weekly lake volume was determined using a staff gauge at the south end of the lake. Using the staging curve provided by Associated Engineering, the elevation was converted to a lake volume and surface area. The surface loss was coupled with the weekly surface area to arrive at a weekly surface loss volume in acre feet. The accuracy of these numbers is somewhat limited because wind distorts the true depth of the lake. Therefore, weekly water balances are difficult to compute, however, on a season long basis, the numbers make better sense.

## Salt Balance

Using the water volumes calculated from the collected data, a salt balance for the lake was carried out. The salt load carried by the water was computed using the formula:

TDS (mg/l) = 765(EC)1.087 (Cheng et al. 1983)

Weekly water samples were collected at the inlet canal and three sites along the north-east shore by irrigation branch staff. Pumping volumes were grouped by proximity to each sample site and the tonnes of salt removed were determined. The tonnes of salt removed by spill and tonnes entering through the inlet canal were determined in the same way. Run-off from Middle Coulee and Hummel's Coulee has been assigned an average EC of 1.5.

In an attempt to represent a more accurate estimation of the actual salt content of the lake itself, water samples were collected throughout its entire length using a boat. Using these water samples and their location relative to the weekly samples collected from the three shore locations, the volume of the lake represented by each shore sample was determined. This was done by partitioning the lake into zones of similar water quality and using the area of the zone to determine volume. This method assumed that the lake has a very similar bottom profile throughout its entirety.

Using this method, it was determined that the Doenz site water quality represented 4% of the lake volume, the mid lake sample represented 60% of the lake volume, and the Reese site water samples represented 36% of the lake volume.

# RESULTS

## Water Balance

For the period May 1 to October 16, 1991 inflow was measured at 10664 ac-ft. An additional 1110 acre feet of run-off is estimated to have come from Hummel's Coulee. Spill was measured at 5360 ac-ft, pumping at 1745 ac-ft, and surface losses at 2997 ac-ft. Using a May 1 lake volume of 8229 ac-ft, the October 16 lake volume should have been 9901 ac-ft. The actual measured volume on October 16 was 9202 ac-ft for a difference of 699 ac-ft. This is equivalent to 7.2% of the average

lake volume for the season or 108 mm of lake depth. The staging curves may not be accurate enough to determine whether this is significant or not. Wind also affects the accuracy of lake elevations. In addition, a very significant run-off may have occurred on June 21, when a large thunderstorm swept the area. According to farmer observations, more rain fell at the north end of the lake than at our recording site. Run-off from the numerous coulees leading into the lake was not accurately recorded. The estimate for the run-off from Hummel's Coulee is based on a measuring site approximately 2 kilometers from the lake, and no water samples were taken from this tributary. In addition, a small amount of water was pumped over the dike at the north end of the lake, and this may have affected both the water and salt balance. The flow monitoring station measuring spill was not operating for several days in June, and spill values were interpolated for this time period. Based on the expected accuracy of the staging curves, evaporation estimates and rainfall recording, the difference between the expected lake volume and measured volume is relatively small. Therefore, the estimated and measured volumes of all the variables in the water balance appear to be realistic and relatively reliable.

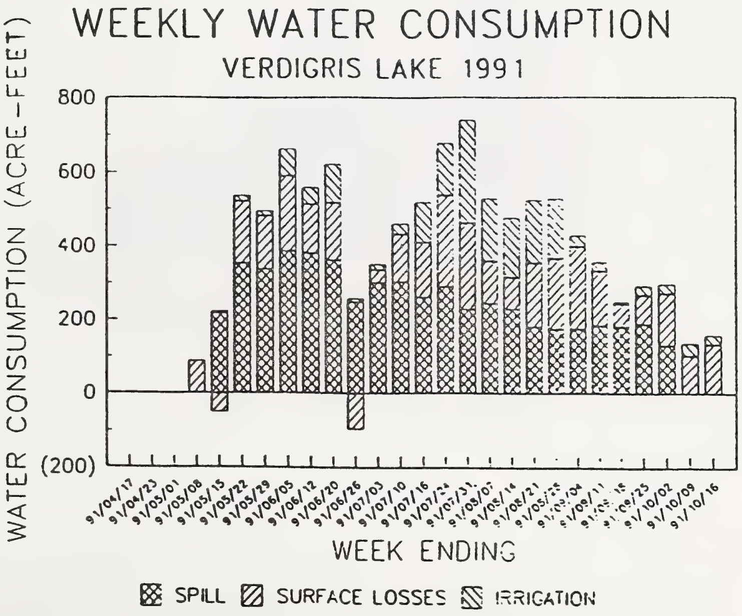


**FIGURE 3**

1991 was not a "normal" climatic year for the Verdigris area. Lake evaporation was estimated at 468 mm (18.4") for 1991 while the normal expected evaporation is 750 mm (30"). Irrigation withdrawal was measured at 1745 ac-ft (9.1"/acre) while the normal expected irrigation would be 2300 ac-ft (12"/acre). These lower than expected water demands are due in large part to a great deal of very timely rain in the area and a cooler than normal spring and early summer.

## Salt Balance

Using data collected from April 23 to October 16, salt introduced into the lake was 5873 tonnes, removed by spill was 7058 tonnes, and removed by irrigation was 1633 tonnes, for a net loss of 2818 tonnes.

Using the shore sampling method of determining lake salt content, initial salt content of the lake on April 23 was 10541 tonnes and the final content on October 16 was 8384 tonnes. This represents a net removal of 2157 tonnes from the lake. Our weekly salt balance figures estimate the expected salt removal to be 2818 tonnes for a difference of approximately 661 tonnes.

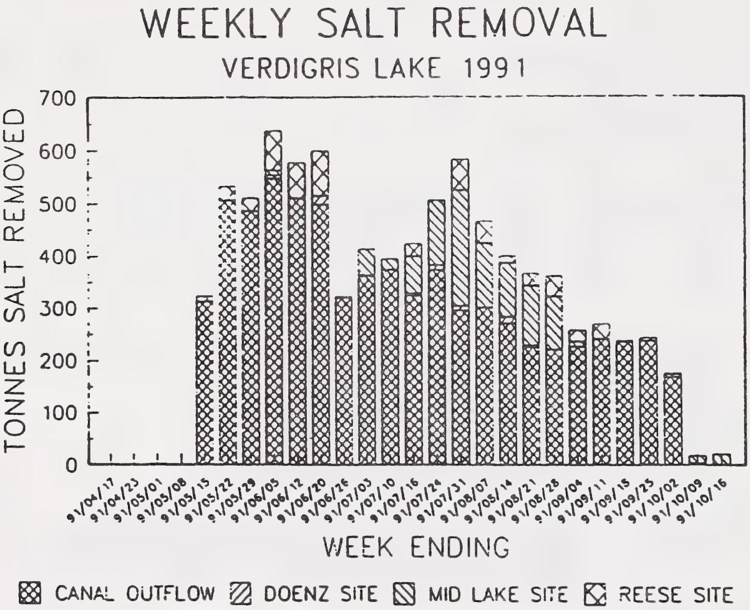


FIGURE 4

Errors in the salt balance may come from several sources. The estimation of salt content based on shore sampling is quite arbitrary and may not accurately reflect the true salt content of the lake. Significant run-off events carried a great deal of salt into the lake and because of their short duration, accurate estimations of the salt content of the run-off water is difficult. If a representative water sample was not obtained for this flow, a considerable error may have resulted.

## CONCLUSION

Based on the best information available, there does not appear to be a significant unknown source of salt affecting Verdigris Lake.

Evaporation load is typically 1.75 to 2.0 times higher than irrigation demand from the lake.

Highest irrigation demands tend to occur early in the season, when water quality tends to be poorest.

Water movement and therefore water quality improvement is hindered by dense weed growth throughout most of the lake. This results in minimal improvement of water quality at the southern end of the lake throughout the season.

Major storms can result in significant additions of water and salt into the lake.

# CORRELATION OF SUGAR CONTENT IN SUGAR BEETS TO TIMING OF IRRIGATION WATER

R. Riewe, G. Cook, V. Ellert, R. Collett[1]

## INTRODUCTION

A survey was undertaken in 1990 and 1991 to determine whether timing of irrigation water has any effect on sugar content. Information from the survey is to be used to update crop water use versus yield curves presently used for sugar beets. An additional objective was to evaluate present day irrigation management practices to determine the best possible irrigation schedules for maximum sugar production.

## METHODOLOGY

With the assistance of the Alberta Sugar Beet Growers Association, a total of 49 farmers and 74 fields participated in this survey.

On a weekly basis, soil moisture was determined for each field. The "feel method" was used for this determination. Soil moisture samples were taken at 25cm increments to a depth of 1.0m.

Prior to the fields being monitored, each field was inspected and appropriate soil moisture monitoring sites were selected. Irrigation and rainfall information was collected on a weekly basis from the irrigation farmer.

## RESULTS

From the information collected over the past two years, no definite correlation exists between the total amount of sugar produced (% sugar x tonnage) and the amount of water used by the crop. In 1990, the amount of sugar produced from one mm of water consumed, varied from 6.5 to 9.5 kg/acre. In 1991, this ranged from 5.6 to 7.4 kg/acre. The average amount of sugar produced was 8 kg/acre in 1990 and 7 kg/acre in 1991.

Davidoff and Hanks found similar results in that the level of irrigation had no consistent effect on sucrose levels prior to harvest.

Method of irrigation had no bearing on total sugar production or percent sugar in either year of the study.

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Of the 37 fields monitored on this project in 1991, 27 fields (73%) exceeded both the factory average for percent sugar and total sugar yield (Figure #1). In comparison, 34% of the fields in 1990 exceeded both the factory average for percent sugar and total sugar. 57% of the fields exceeded the factory average for percent sugar and 59% exceeded the factory average for total sugar produced. Of the 15 fields that exceeded the factory average for total sugar produced, 33% had total percent sugar values that were lower than the factory average (Figure #2).

In 1991 the crop consumptive use varied from a low of 394mm to a high of 690mm. Consumptive use values for the Coaldale-Chin block and Taber-Purple Springs block were nearly identical, 491mm Coaldale-Chin area and 474 mm Taber-purple springs area. In 1990, the average consumptive use for these same blocks were 478mm and 427mm respectively.

Tonnes of sugar beets produced ranged from a low of 12.8 to a high of 27.95. Figure #3 compares the crop water use vs. crop yield for all fields monitored in 1991. Information for the 1990 crop season is also included for comparison. As in 1990, the field with the lowest crop consumptive use exceeded the factory averages for both percent sugar and total sugar produced (Field L, Figure #1). Because of poor record keeping by the farmer, more irrigation water may have been applied than what was actually recorded.

The crop with the highest crop consumptive use slightly exceeded the factory average for percent sugar, but was well below the factory average for total sugar produced (Field H, Figure #1). Only 14% of the fields monitored met the water requirements of the crop, as outlined in the Irrigation Management Handbook. 32% of the fields met 91% of the crop water requirement and 27% of the fields met 82% of the crop water requirements. In 1990, only 11% of the fields met 91% of the crop water requirement and 15% From this, it is apparent that irrigation farmers continue to under-irrigate their crops.

It is recommended that the last irrigation on sugar beets occur the last week of August to the first week in September. Ceasing irrigation at this time would allow the root zone to dry down sufficiently for digging purposes. By stressing the crop, percent sugar content is increased. Over-watering late in the growing season causes sugar beets to retain moisture, increasing tonnage but not dry matter, thus decreasing percent sugar. At the time of harvest, 43% of the fields monitored had soil moisture conditions greater than 50% available moisture. Of this group, 27% exceeded the factory average for total sugar produced. Of those fields which had available soil moisture levels less than 50%, 19% exceeded the factory average for total sugar produced.

In 1990, 83% of the fields monitored had tonnages that exceeded the grower average of 17.08 tonnes/acre. In 1991, where the grower average was 19.30 tonnes/acre percentage of fields exceeding the average dropped to 59%. Average tonnage for the 47 fields monitored in 1990 was 18.81 tonnes/acre. In 1991, the average of the 37 fields monitored was 20.12 tonnes/acre.

## CONCLUSION

At the present time, sugar beet growers continue to strive to produce the maximum tonnage. Even though the Alberta Sugar Company now pays sugar beet growers based on percent sugar, beet growers still are able to make a profit in raising sugar beets by striving for high tonnage.

Good management of all input factors is required to obtain both high percent sugar content and high total sugar produced per acre. Fertilization, plant populations, weed control, seed bed preparation, are only a few of the factors that affect sugar beet production. Irrigation plays a major role in reaching the goal of high percent sugar and total sugar produced. As the direction of Alberta Sugar changes from strictly tonnage-oriented production to a combination of percent sugar content and total impurities present, sugar beet growers will have to change their management practices to meet these new requirements.

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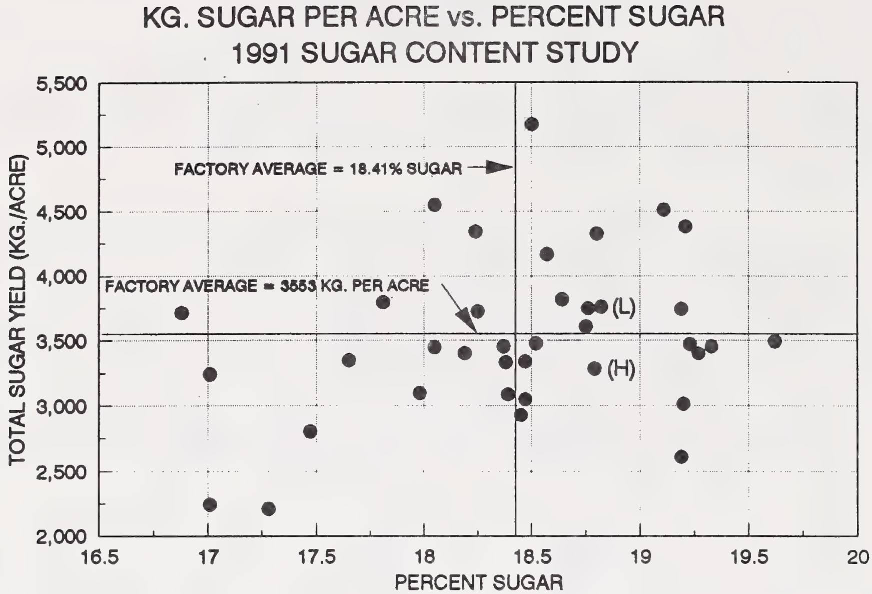


FIGURE #1

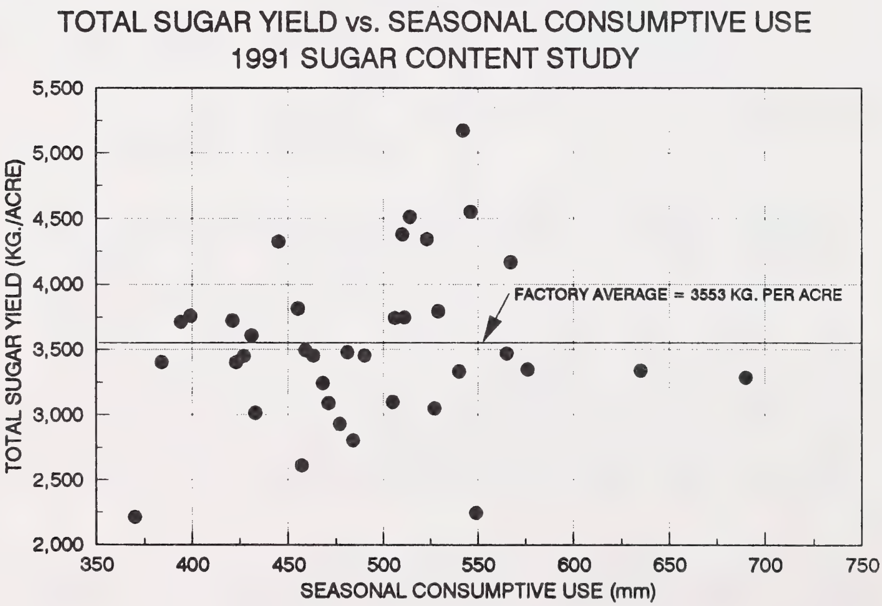


FIGURE #2

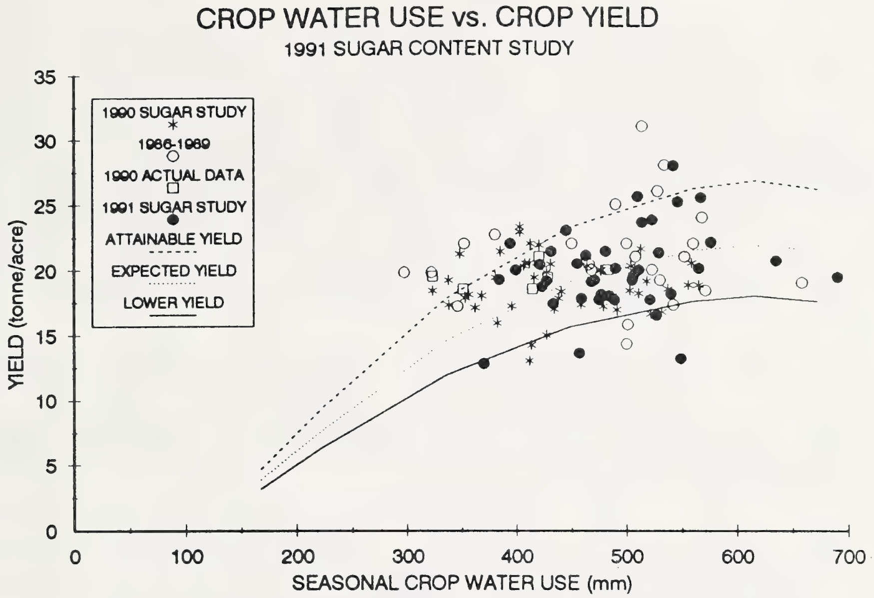
CROP WATER USE vs. CROP YIELD
1991 SUGAR CONTENT STUDY
1990 SUGAR STUDY
1986-1989
1990 ACTUAL DATA
1991 SUGAR STUDY
ATTAINABLE YIELD
EXPECTED YIELD
LOWER YIELD
YIELD (tonne/acre)
35
30
25
20
15
10
5
0
0
100
200
300
400
500
600
700
SEASONAL CROP WATER USE (mm)

FIGURE #3

# INFLUENCE TIMING OF IRRIGATION WATER HAS ON CROP YIELD

R. Riewe, B. Handerek[1]

## INTRODUCTION

The purpose of this report is to look at the effects of timing of irrigation on crop yield. Soft wheat (variety: Fielder) was grown under irrigation using a variety of irrigation schedules (Figure #1). Yield reductions ranged from 16% (741 kg/ha.) to 33% (1548 kg/ha.), depending on the soil moisture stress maintained by the specific irrigation schedules. Where high soil moisture conditions were maintained, yields ranged from 91% to 100% of treatment A, the control.

This study was developed to study the effect of various irrigation schedules on crop production. The three main factors on which irrigation farmers base their irrigation scheduling (plant growth, soil moisture, and time of year) were used to create the 8 irrigation schedules for this project.

Figure 1: Description of Different Irrigation Schedules

A. 50% of available moisture depleted.
B. 50% of available moisture depleted in the top 50 cm. of the root zone only.
C. 50% of available moisture depleted until cut off date of June 30.
D. 1990: 75% of available moisture depleted.
   1991: 50% of available moisture depleted until the flag leaf is visible. 25% of available moisture depleted from flag leaf until harvest.
E. 75% of available moisture depleted until the flag leaf is visible. 50% of available moisture depleted from flag leaf to harvest.
F. 50% of available moisture depleted until the flag leaf is visible. 75% of available moisture depleted from flag leaf to harvest.
G. 25% of available moisture depleted until the flag leaf is visible. 50% of available moisture depleted from flag leaf to harvest.
H. Dryland.

Note: Once these depletion levels are reached, plots are then irrigated back to field capacity.

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## METHODS

The Project area located in the S.E.1/4 of 2-10-21-W4 (approximately 10 km. from Lethbridge) was cultivated and seeded by the co-operating owner/farmer. The site was seeded at 123 kg/ha in 1990 and 112 kg/ha in 1991. Soft wheat was seeded on May 4 in 1990 and April 25 in 1991. 90 kg of actual N. was applied in each year using a broadcast spreader. Buctril M herbicide was applied according to manufacturer's recommendations in both years for broad leaf weed control.

The plots were situated using a randomized block design. Each treatment was replicated 3 times. The size of each plot was 6.1 m x 12.2 m (20' x 40') with a 18.3 m (60') buffer zone between each plot (E-W axis) and a 9.15 m (30') buffer zone between each row (N-S axis).

Irrigation water application was monitored with a Tru-chek rain gauge located in the center of each plot. During the 1990 season rainfall was measured by means of a rain gauge located just outside the project area and other climatic information (air temperature, solar radiation, and wind travel) was obtained from Agriculture Canada at Lethbridge on a weekly basis. In 1991, an automated weather station was set up at this location. This weather station consisted of a tipping bucket rain gauge, temperature sensor, solar radiation sensor, anemometer, data logger, and cellular phone.

Soil moisture was determined at 25 cm intervals to a depth of 100 cm with a Troxler Nuclear Moisture Gauge. Immediately after seeding, 1.2 m long aluminum access tubes were installed in the center of each plot. Soil moisture levels were monitored at weekly intervals throughout the growing season. To ensure that all water applied to the soil had infiltrated, soil moisture readings were delayed for a minimum 48 hours after an irrigation or heavy rainfall event.

Yield sampling was performed individually for each plot. This was done by hand harvesting three - one metre square samples, randomly selected from within each plot.

The timing and amount of irrigation water required at each plot site was determined using daily climatic data obtained from the meteorological station located at the site and measured soil moisture levels. Actual crop water use was determined using the modified Jensen-Haise equation.

## RESULTS

In all cases, maintaining soil moisture conditions greater than 50% available moisture (treatment A), though out the crop growing season, gave higher consumptive values than treatment A, (104% and 118% respectively for treatments D and G), but gave no significant increases in yield (91% and 100% for treatment D and G respectively). Hobbs and Krogman work showed that by maintaining slightly higher soil moisture thoughout the crop growing season, that crop water use would be 11%

higher than treatment A and crop yields only 5% higher. Table #1 and Figure #2 give the results obtained for two years for this project.

Table 1: Irrigation water applied, consumptive use and crop yield.

| Treatment | Irrigation Water Applied (mm) | Consumptive Use (mm) | Crop Yield (kg/ha) |
|---|---|---|---|
| A | 234 | 351 | 4639 |
| B | 250 | 357 | 4570 |
| C | 154 | 329 | 3898 |
| D* | 240 | 391 | 4234 |
| E | 172 | 311 | 3091 |
| F | 174 | 309 | 3763 |
| G | 306 | 415 | 4637 |
| H | 0 | 194 | 1300 |

* Only one year's data

Maintaining soil moisture conditions at or above the 50% depletion level in the top 50 cm. of the root zone (treatment B), gave similar yield results as treatment A, the control. There was though a 7% to 10% increase in the amount of irrigation applied to maintain the level of soil moisture above the 50% depletion level. Soil moisture conditions below the 50 cm. level ranged from 20 to 45% of available moisture.

Maintaining soil moisture conditions above the 50% depletion level to the end of June (treatment C), and then ceasing irrigations there after has resulted in crop yields being reduced 14 to 25%. Even with above normal precipitation received in July of 1990 (119% above the average for the Lethbridge area), crop yields were still reduced on an average by 18%. In 1991, July rains yielded only 45% of the average precipitation normally received during this time period and yields were reduced by 14%. Table #2 details out the precipitation received at the plot site.

TABLE #2: RAINFALL DATA (mm) FOR 1990 AND 1991

| MONTH | 1990 | 1991 | AVERAGE LETHBRIDGE AREA |
|---|---|---|---|
| MAY | 45.0 | 55.0 | 52.3 |
| JUNE | 21.0 | 106.8 | 86.4 |
| JULY | 47.0 | 18.0 | 39.6 |
| AUGUST | 0.0 | 39.0 | 37.3 |

Stressing the crop at any time during its development can reduce crop yields any where from 30 to 35%. Limiting water during the vegetative stage of crop development as shown with treatment E, has the

greatest impact on yield reductions. Yields were reduced by 33% (1548 kg/ha or 23 bu./acre). Similarly, were water was limited during the reproductive stage of crop development (treatment F), yields can be reduced by as much as 19% (876 kg/ha or 13 bu./acre). Regardless of when the water was limited, both treatment had nearly identical crop water uses, 309 mm (treatment F to 311 mm treatment E). In both cases, the amount of water used by the crop was only 12% less than treatment A.

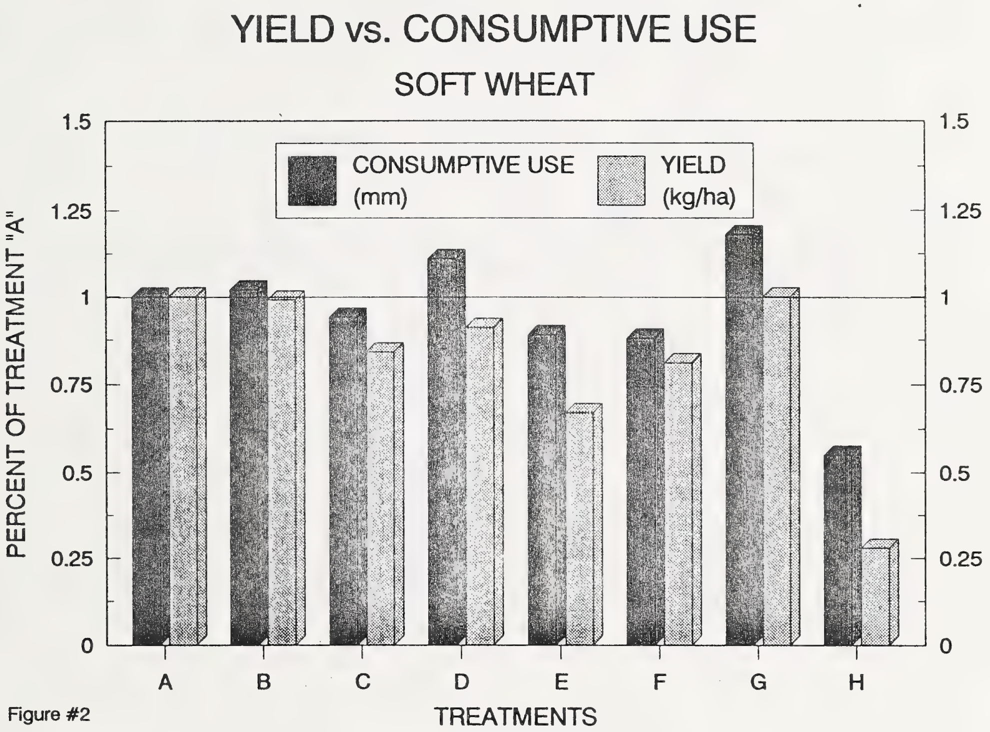


Figure #2

## SUMMARY AND CONCLUSIONS

In summary, the preliminary findings for the past two year indicate that significant yield losses can and will occur if producers fail to understand the importance of the timing of irrigation on crop production. Irrigation management is an important tool that producers can use to eliminate poor crop yields.

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# LEPA DEMONSTRATION PROJECT

M. Rigby[1], G. Cook[2], B. Farries[3]

## INTRODUCTION

In order to increase irrigation application efficiency for center pivot irrigation systems, Senninger Irrigation of Orlando, Florida devised a **L**ow **E**nergy **P**recision **A**pplication (LEPA) sprinkler head which can discharge water 20 - 30 cm above the ground surface with 9 psi inlet pressure to minimize wind drift and maintain excellent system uniformity. The LEPA system not only increases application efficiency, but reduces energy requirements and provides a chemigation option. This equipment was developed mainly for the Texas High Plains with a great deal of the initial work being performed by Texas A & M University.

LEPA is a product which could be suitable for some applications in southern Alberta. There are many center pivots in operation, and the relatively high winds experienced throughout the irrigation season demand an alternative to standard impact sprinkler application. There are, however, several aspects of LEPA which limit its potential implementation and success. Because the LEPA system discharges water at very low elevation and pressure, application rates are very high, requiring very flat terrain with highly permeable soils in order to prevent run off. To counteract possible run off, the LEPA system should be operated in conjunction with some sort of reservoir tillage operation. Reservoir tillage is most effective in row crop applications, although broadcast reservoir treatments are possible in small grains and forages. The reservoir treatments do, however, make the ground very rough for equipment travel. In order to reduce the costs of the LEPA system conversion, heads are spaced so as to discharge into every other row, which once again increases application rates. In order to maximize the benefit of precise application and reservoir tillage, row crops should be planted in a circle so that each head discharges directly into its own furrow. This is of greater importance in tall crops such as corn, where the heads would have trouble travelling through the rows, but is also important so as to minimize the total discharge into any one furrow at any particular time.

LEPA has proven itself in Texas and a large number of center pivots have been converted from standard impact sprinklers or spray heads. Application efficiencies have been proven to reach 90% to 95%, with up to a 20% increase in crop yields under LEPA systems as compared to standard systems. Although the potential application in southern Alberta is limited by system types, crop mixes, soil types, and topography, LEPA may prove to be a viable means of increasing application efficiency and reducing energy consumption for some irrigators. The built in ability to effectively chemigate may also prove to be valuable, especially for special crop producers.

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## METHOD

The LEPA trial was performed as a co-operative effort between the Vauxhall and Taber offices of the Irrigation Branch of Alberta Agriculture and the Ag-Canada Substation located in Vauxhall. The LEPA heads were provided by Senninger, with other necessary equipment being supplied by New Way Irrigation of Taber. The center pivot converted was a three tower Zimmatic. The third span was converted to LEPA with the remaining two spans being left with their original impact sprinklers. Yield and soil moisture data was collected to determine the benefits of the LEPA conversion versus the standard sprinkler package.

The three tower pivot is towed between two circles. (See attached plan.) The north circle was planted to corn and farmed in the round. Reservoir tillage was incorporated using a dammer diker on the LEPA span in its entirety and in several places under the standard spans. The south circle was planted to barley. This area was broadcast diked using the dammer diker under the LEPA span and diked in several areas under the standard spans. The LEPA head was used in irrigate (spray) mode and furrow bubbler mode on the corn rows, while only being used in irrigate mode on the barley.

The LEPA heads were nozzled so as to match the flow through the impact sprinklers they replaced. Application rates through the LEPA sprinklers were approximately 200 mm/hr in spray mode. This application rate is comparable to a LEPA package mounted on a 400 meter center pivot operating at 57 l/s (1300' at 900 US gpm). Common application depths were 25 mm per irrigation, with up to 50 mm applied in spray mode. The soil types under the center pivot were sandy loam to loamy sand. The expected infiltration rate for this soil type is 25 mm/hr.

## RESULTS

The main objective of the demonstration was to prove that LEPA is a manageable alternative to standard sprinkler packages on center pivots. This was demonstrated through the use of the reservoir tillage system, farming in the round, and the successful operation of the LEPA sprinkler heads at application depths similar to the standard sprinkler heads. The LEPA system operated at flows and pressures as designed, with no significant mechanical problems.

Corn yields, as determined on a dry matter basis using a weigh cart, were 13.2 T/ha for the LEPA span and 12.0 T/ha for the standard sprinkler span. Barley yields were measured at 5.3 T/ha for the LEPA span and 5.9 T/ha for the standard sprinklers. The demonstration was therefore inconclusive in regards to potential yield increases under LEPA. Unfortunately, due to higher than normal rainfall, only about 20% of the crop water requirement for the corn and barley crops in the demonstration was supplied by the irrigation system. In other years, when crop water demand would exceed system capacity, a yield benefit under the more efficient LEPA system would be expected. Monitoring of soil moisture using a neutron probe showed no measurable differences in soil moisture levels between the LEPA span and the standard span. However, there were no detrimental effects to the crop as a result of the application of water through the LEPA system or the field management practices incorporated to control the run-off from the high LEPA application rates.

Both the bubbler and irrigate mode of operation were used for the demonstration. The bubbler caused more runoff problems, especially where reservoir tillage was not in place. In the barley crop, the irrigate mode was used exclusively. Although the irrigate mode does not provide the maximum reduction in wind drift, the low elevation of the heads eliminated most of the drift problems and produced a more manageable application rate than bubbler mode. In the corn, the irrigate mode was able to penetrate through the corn rows and place water in all of the furrows. In the barley, the heads operating in irrigate mode were placed approximately 25 cm above the crop canopy, and actually resulted in less lodging of the crop as compared to the sprinkler irrigated areas.

## CONCLUSIONS

The LEPA system was successful in minimizing wind drift, both in the corn and the barley crop. The irrigate (spray) mode created less run off than the bubbler mode. The irrigate mode seemed to be the most reasonable mode of operation in that it maximized application efficiency by avoiding most of the wind drift while also minimizing application rates.

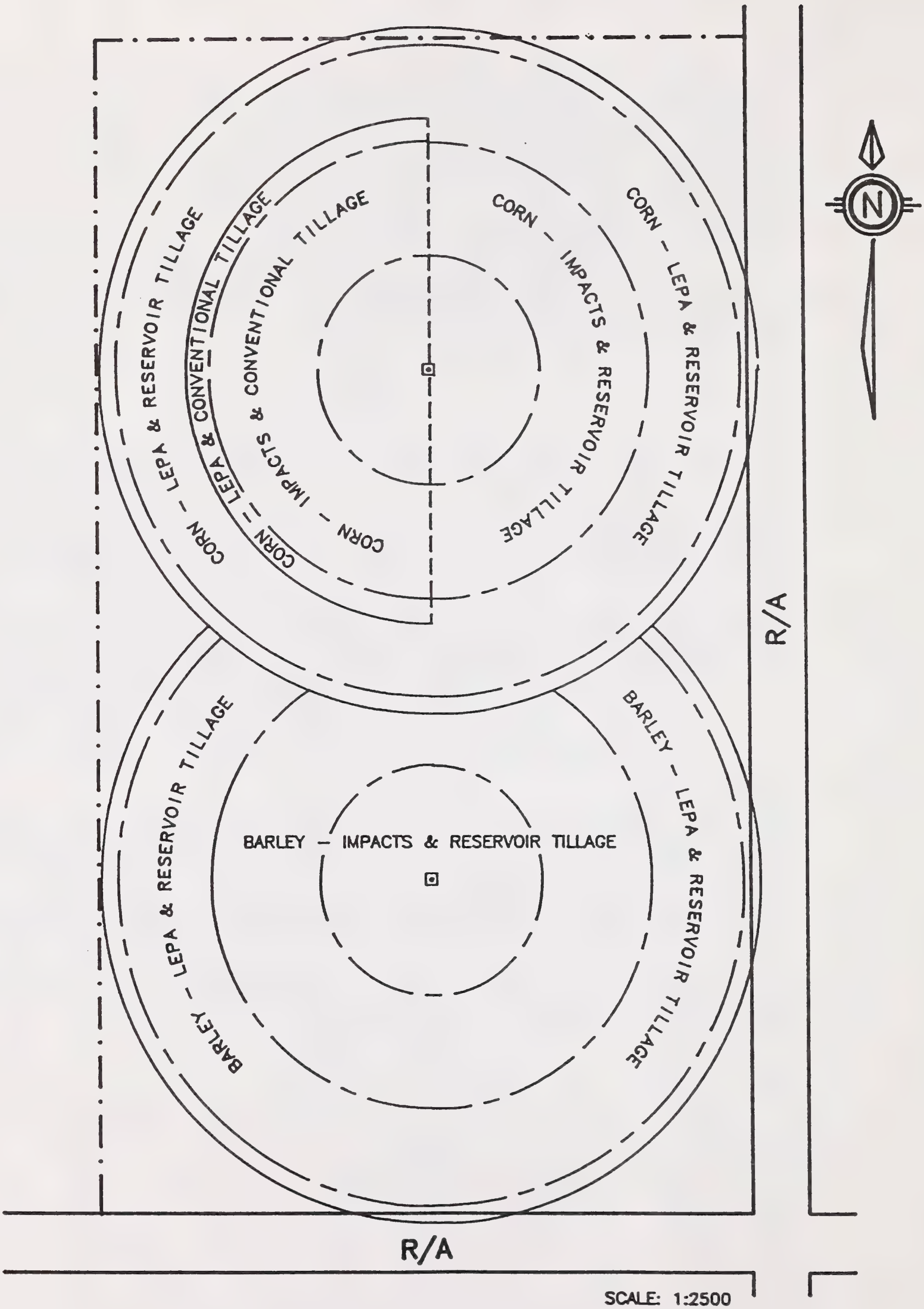
Several of the crop management strategies implemented under the LEPA demonstration could be implemented under other low pressure sprinkler systems to reduce runoff and therefore enhance irrigation application efficiency while still enjoying relatively low energy costs.

The high cost of the LEPA system appears to be prohibitive relative to the potential cost savings in southern Alberta. Energy costs, water costs, and water requirements may not be high enough to encourage operators to convert existing systems, or order new center pivots with LEPA equipment.

The LEPA system should be assessed versus more conventional and less costly low pressure sprinkler options to determine the most cost effective means of irrigation.

The reservoir tillage left the field very rough for equipment travel and methods of removing the reservoirs ahead of harvest equipment should be investigated.

Investigation should continue into methods of increasing soil infiltration rates and/or surface storage while leaving a smoother path for equipment travel.




GENERAL LAYOUT PLAN
LEPA DEMONSTRATION
AG CANADA SUB-STATION (VAUXHALL)

# ELIMINATION OF AQUATIC WEEDS IN IRRIGATION CANALS USING TRIPLOID GRASS CARP

S. Jonas, D. Lloyd, J. Stewart[1]

## INTRODUCTION

The objective of this five-year cooperative research study is to study the utilization of sterile triploid grass carp (Ctenopharyngodon idella) to provide an overall biological control of problem aquatic vegetation in the 8000 kilometers of open canal systems in Alberta. This report presents results from Year III.

The five-year research plan is coordinated by the Committee on Biological Control of Aquatic Vegetation (CBCAV, 1990). The CBCAV consists of Alberta Agriculture (Jonas, Chalmers and Lloyd) in cooperation with Alberta Forestry, Lands and Wildlife (Drouin, Bishop and Fitch), Alberta Environment (Burland, Moore, Fritz, and Smiley), Agriculture Canada (Allan) and the Alberta Irrigation Projects Association (Wilde). In addition, the Lethbridge Community College (Beck) is involved.

In year one of the study (1988/89), approximately 5000 four-day-old larval grass carp were imported into Alberta from Florida. The fish were raised for one year under quarantine indoors at the Alberta Environmental Center in Vegreville. Ten component task studies were undertaken by members of the Committee.

In year two (1989/90), one thousand of the certified triploid fish were stocked in shallow dugouts in southern Alberta. Work continued on the technical tasks as outlined in the five-year research plan. Fish were over-wintered in deep oxygen-rich dugouts.

## DISCUSSION OF TASKS

**1. Indoor Rearing**

**A. Alberta Environmental Center (Moore, Smiley):** On May 14, 1990 the shipment of 3000 triploid larval grass carp was received from Florida. The fish at the time of receipt were approximately 6 mm long and weighed an average of 1.8 g.

A total of 2059 confirmed triploid grass carp (1990 stock) were transferred to Lethbridge; 800 on August 28, 1990, 312 on August 31, 1990 and 946 on September 25, 1990. In addition to these shipments, 34 confirmed triploids, 1988 stock, were shipped to Lethbridge on July 4, 1990.

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[1] Irrigation Branch, Irrigation and Resource Management Division, Alberta Agriculture, Agriculture Centre, Lethbridge, Alberta, T1J 4C7.

<u>B. Lethbridge Community College (Beck):</u> The rationale for artificial rearing was identified as a means of providing an extended grow-out period to insure a sufficient size (25 - 30 cm) of fish suitable for irrigation canal introductions in the spring.

In August, 1990 the CBCAV entered into a formal agreement with Lethbridge Community College (LCC) to provide technical assistance, space, equipment and operational costs to raise 1000 triploid grass carp at the Animal Husbandry Facility (AHF).

Throughout the 167 day rearing period at the AHF fish rations and feeding strategies were experimentally evaluated.

On May 29, 1991, 772 fish were sampled and stocked into dugouts and the Raymond Irrigation District canal. The combined fish biomass artificially reared was 78.0 kg on May 29, 1991. Based on an initial fish total weight of 11.57 kg an average weight increase of 0.36 g/day over the 249 day rearing period was achieved, representing an increase of 821%.

An 82% survival was realized over the 249 day rearing period. Electrical and mechanical failure on April 04 resulted in tank de-watering and a loss of 113 fish. Additional losses of 60 fish were attributed to nitrite toxicity, physical damage and unknown causes. Losses observed during the later stages of the rearing period were attributed to vitamin deficiencies.

<u>2. Stock Fish, Monitor and Recovery (Bishop, Bidgood)</u>

At some unknown point a number of the fish escaped through a dislodged bar-screen (caused by high flows and channel erosion) and migrated upstream into one of the control sections of the canal. In mid September the fish were noticed in the upstream section and recovery efforts began immediately.

Several recovery methods were tried: seining with a specially designed net, backpack electro-shocking and in-stream trap with leads. None of the methods were very successful resulting in only a few dozen fish being recovered. Good numbers were obtained using the Fish and Wildlife's electro-shocker boat. However, not all fish were recovered until the canal was drained for the season in late October and the remaining pools electro-shocked.

Triploid grass carp were found to utilize in-stream structures as hiding places, thus it is almost impossible to recover all fish while the system is in use.

Fish that were recovered from the small pools that remained in the canal after seasonal shutdown were badly bruised and many had cuts and scrapes.

<u>3. Aquatic Plant Biomass and Standing Crop (Allan, Burland)</u>

Vegetation sampling commenced on July 30 and continued on a biweekly basis until the middle of September. Sampling was conducted at three randomly chosen sites within the treated area.

In order to determine grass carp efficacy in the canal, the amount of standing crop biomass in Reach #2 (treated area) was compared to the amount of standing crop biomass in Reach #3 (control area) on each of the four sampling dates.

The results indicate that the fish grazed the sides first with the south side of the canal preferred. The plant material in the center of the canal would have been the oldest and perhaps the toughest, hence the small

size of the fish of the initial stocking may have had some influence. The experimental section was reduced by 84% of the check section.

## 4. Pathology Services (Fritz, Chalmers)

Regular testing of fish ensures that no new pathogen is introduced into Alberta waters and that all fish used in this study are certified triploid.

Regular health checks on the fish include: bacteria, viral, parasitic and other non-specified agents. Field checks were undertaken by Dr. Chalmers while the extensive laboratory testing was coordinated through the Alberta Environmental Center (AEC) in Vegreville.

One hundred and eighteen routine histopathology evaluations of carp held at the AEC (1990 stock) were made on randomly selected or suspect fish during the period May 1990 to January 1991.

In late August 1990, 75 randomly selected grass carp (1990 stock) were submitted to the Department of Fisheries and Oceans Freshwater Institute in Winnipeg, Manitoba for bacteriology and diagnostic viral evaluation.

After investigations of fish kills it was determined that grass carp stock in two of the wintering dugouts (Fairfields and Hepps) had become infected with a protozoan (*Chilodonella* sp.).

A standard operating procedure for the transport and treatment of grass carp and wintering ponds (SOP #2350-AJ4/AN/AQ/22) was developed and proposed for implementation by Dr. D. Fritz and K. Smiley in September of 1990.

A total of 2250 blood letting / ploidy determinations were conducted between August 1 and September 21, 1990. This total includes 143 blind quality assurance/quality control samples (6.4%). Of the 2097 grass carp sampled, 2059 (98.2%) were found to be triploid and 28 (1.3%) were found to be diploid. Another 10 (0.5%) were found to be polyploid. All diploid and polyploid fish were isolated and subsequently terminated.

In addition to the blind QA/QC samples, a larger blood sample was taken from 105 grass carp for chromosome culture and karyotyping. All the blind QA/QC samples were identified and 100% of the chromosome culture confirmed the Coulter CounterR determinations.

## 5. Water Quality (Allan)

The 1989 and 1990 sampling was done at the same time as the biomass measurements were made and revealed an improvement in water clarity, less turbidity and decreases in total phosphates and nitrates. Total solids and total dissolved solids seemed to increase but these measurements will be checked in greater detail in 1991.

In dugouts there is a general increase in ammonia at the time of ice breakup. This occurs on the bottom first and moves to the surface where mixing occurs when the dugout is totally free of ice. This buildup ranges from 0.01 to 0.03 ppm before ice breakup to levels as high as 0.3 ppm as the last ice leaves. Once mixing occurs the levels return to the 0.01 to 0.03 range and then below detection in mid to late May. This buildup could be prevented by mixing the water earlier in the season to prevent stratification in the deeper (winter) dugouts.

## 6. Water Temperatures (Jonas)

Maximum and minimum water temperatures were recorded at various locations in southern Alberta.

Examination of the results show that optimum feeding is likely to occur over an eight week period, from the last week in June to the middle of August. There is, on average, a difference of 3.6°C between daily maximum and minimum temperatures.

It is recommended that at least one station (preferably on the canal stocked with fish) record temperatures on an hourly basis. This will give an indication on how many hours per day will fall into the optimum feeding range above 21°C.

## 7. Predacious Fish study (Jonas)

The collection, sorting and grading of fish is done manually after the water is turned off in mid-October. Fish samples are collected with a dip net and recorded in one of three categories according to fork length: under 300 mm, between 300 mm and 600 mm and over 600 mm.

Seven sites on the Raymond main canal have been sampled in 1988 and 1989 and 1990.

Overall, the predacious fish recovered in the 1990 survey were smaller in size and fewer in number than those taken in previous years. This was expected due to the installation of a fish barrier which did not allow movement of larger fish into the test section.

## 8. Containment and Fish Barriers (Jonas)

In the spring of 1989 a fish barrier (now referred to as barrier #2) was designed and installed upstream of the test section. Barrier #2 consisted of iron pipe (38 mm dia.) welded vertically on a 2:1 slope with spaces of 25.4 mm between them.

Before the 1990 irrigation season, three additional fish barriers were installed in the Raymond Main Canal (barriers #3, #4, and #5). The floor and sides of the barriers consists of three pre-cast concrete panels forming a pad across the canal cross-section. A screen made of horizontally welded metal bars spans the opening. The bars are 13 mm in diameter and have spaces of 25 mm between them.

Early in the 1990 irrigation season it became apparent that barriers #3,#4, and #5 were inadequate to withstand the high flows. The screens had to be cleaned manually every 4 - 6 hours, 7 days a week and the horizontal bars proved to be more difficult to clean than the vertical configuration. The bar screens quickly became plugged with weeds causing water to wash under the bottom and sides of the concrete panels. Sand bags were used to seal holes, but more wash-outs occurred on barriers #4 and #5 and they were abandoned. Fortunately grass carp had not yet been stocked in the canal when structures 4 and 5 washed out.

Barrier #3 was saved, but an extension had to be built and added on top of the catwalk because of the unusually high flows

Barrier #2 remained sound and with fortified barrier #3 it was possible to isolate approximately 1 km of canal to be used as a test section.

## CONCLUSIONS

1. The potential of rearing triploid grass carp under artificial conditions to a stockable size of 25 - 30 cm. is feasible on a small scale (1000 - 2000 fish).

2. The grow-out of larger numbers of fish to a stockable size may be achieved in outdoor dugouts and ponds over the course of one summer growing season under ideal conditions.
3. The results of the quantitative indices utilized in the 1990 stocking model (84 and 28 kg/ha) for the canal study reaches are inconclusive because of barrier failure.
4. The experimental section of the canal was reduced by 84% plant biomass of the control site.
5. The gill protozoan parasite (Chilodonella sp.) was isolated from fish in two wintering dugouts (Fairfield's and Hepp's). A standard operating procedure for the transport and treatment of grass carp and wintering dugouts was developed and implemented in September of 1990.
6. Regular health checks conducted in 1990 - 91 revealed no evidence of pathogenic bacteria, viral or other parasites associated with the grass carp that were tested.
7. Of the 2097 grass carp sampled in 1990, 98.2% were found to be triploid. All diploid and polyploid fish were isolated and subsequently terminated.
8. An improvement in water clarity, less turbidity and decreases in total phosphates and nitrates was observed in the canal study area in 1990. Total dissolved solids and total solids were observed to be slightly higher during that same period.
9. A general increase in dugout unionized ammonia was observed at the time of ice breakup with ranges of 0.01 - 0.03 mg/l.
10. Grass carp feeding intensifies with an increase in temperature. Regular feeding begins at approximately 13° C and optimum feeding is reached at temperatures above 21° C.
11. Optimal feeding in the canal occurs over an eight week period, from the last week in June to the middle of August.
12. Fish barrier installations have effectively reduced predator fish within the study area.
13. Fish barriers with horizontal bars proved to be comparable to the vertical configuration in weed and debris passage. For the ease of cleaning, vertical bars are preferred.
14. Bar spacing at 25 mm prevented fish of 200 mm or larger from passage beyond the study area.

## RECOMMENDATIONS

1. An artificial rearing program should be continued through 1991-92 to further evaluate the holding and rearing of fish of various sizes and to assess appropriate feeding strategies that would include artificial and natural diets.
2. A bioenergetic study should be incorporated into the 1991-92 tasks.
3. It is recommended that an evaluation of the technology and processes for maintaining and spawning brood fish and fry rearing be undertaken early in the fall of 1991.
4. Summer rearing of grass carp in dugouts will continue in addition to utilizing net pen installations.
5. Earlier stocking in the canal in 1991 is recommended (mid-May to June 1).

6. A pre-wintering dugout treatment of formalin is recommended prior to fish introductions into dugouts susceptible to Chilodonella sp. infestations.
7. Winter mixing (aeration) is recommended to prevent stratification in the deeper wintering dugouts in late fall and early spring.
8. Temperature monitoring should continue in 1991. Temperatures in the canal test section should be recorded on an hourly basis.
9. A strengthened vertical bar screen will be designed and in place prior to spring 1991 canal introductions. A concrete cut-off curtain will be poured in place across the front of each barrier.
10. Research into other methods of fish containment, such as sound barriers, should be conducted.

# EVALUATION OF SINGLE DELIVERY FLOW MEASUREMENT DEVICES FOR IRRIGATION IN ALBERTA

S. Jonas[1], J. Prozniak[2]

## INTRODUCTION

This Farming for the Future financed research project, jointly undertaken by Alberta Agriculture and MPE Engineering, involves the review, selection, and testing of flow measurement devices suitable for use on individual irrigation farm turnouts. The project parameters include fabrication of prototypes and installation of these devices at locations within a chosen irrigation district.

This study required an assessment of existing turnouts to determine flow measurement requirements due to the varying methods used to deliver water to the individual user. Three blocks were investigated and used to determine flow measurement requirements.

The survey of irrigation district delivery systems indicated that flows could be measured with pipe flow meters placed on the irrigation pumps or with open channel devices placed in the head ditch immediately downstream of the farm turnout or upstream of the dugout. In conjunction with Alberta Agriculture, a literature search was undertaken to select the most appropriate flow devices. Devices selected for testing were to be capable of both manual and automatic operation, with an emphasis on simplicity and low cost.

## METHODOLOGY

### Flow Device Alternatives

Two categories of meter were considered, inline flow meters and open channel flow meters. Inline flow meters consist of insertion mag meters, full bore mag meters, insertion ultrasonic meters, insertion doppler meters, propeller meters, impeller meters, and minor variations of these types of meters. These meters were investigated for reliability, cost, and apparent suitability for flow measurement at farm turnouts. Of these meters the insertion mag meters and insertion doppler meters appear to be most reliable at the least cost. There is good potential that full bore magnetic meters and ultrasonic meters will be very viable if prices are reduced. Propeller and impeller meters were eliminated due to potential trash problems on the propellers and impellers.

A wide variety of open channel flow meters were investigated. These were classified into three categories: fixed sill meters, constant head orifice meters and miscellaneous meters. The fixed sill

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meters include Cipoletti weirs, broad creased weirs, sharp crested weirs, Cutthroat Weir, and the Parshall Flume. All the fixed sill weirs have good potential as meters provided economical units can be produced and economical data loggers utilized. The second category of meters include the Constant Head Orifice Meter and the Vortex Flow Limiter. The Constant Head Orifice Meter was eliminated due to complexity of the required structure and the resulting high cost of fabrication but the Vortex Flow Limiter has good potential for meeting flow measurement requirements. The third category of meters include the vane flow meter, floating weir gate, and the Dethridge meter. The vane flow meters were not considered acceptable due to problems with trash. Floating weir gates appear to have potential for irrigation use, but as of yet remain untested. The Dethridge Meter is a proven metering device having broad use in Australia. It allows continuous flow monitoring and is a positive displacement meter, making it ideal for use in the case of self-levelling dugouts where driving head is small and operation is intermittent.

**Tested Flow Devices**

Of the variety of flow measurement devices investigated and rated according to such factors as ease of fabrication and installation, maintenance, cost, and accuracy, three types of devices have been targeted for testing. Five of the devices are fabricated from precast concrete, selected for its durability, mass production potential, and proven performance in the irrigation industry. One meter was fabricated inhouse and a fabricated steel Vortex Flow Limiter was purchased. All seven devices chosen for testing provide the required measurement accuracy.

Broad-Crested, Cipolletti and Cutthroat Weirs are open channel flow measuring devices suited to low-cost fabrication in precast concrete. These weirs were chosen from the fixed sill category because of durability, simplicity and minimum trash problems. These devices will be used on turnouts which have a head ditch feeding a pumping pond and on some flood turnouts. Limitations of these devices include the possibility of upstream silting, the need for upstream water level measurement, and the required head loss across the structure limits their use to turnouts with excess grade. Manual measurement can be achieved with a staff gauge, though for effective flow measurement, a data logger is a requirement.

## RESULTS

**Test Results**

Investigations of inline flow meters and assessment of meters at installed sites indicates that the performance of the mag meter and the doppler meter is satisfactory and the cost of the meters is relatively low. In the course of this three year study, meter manufactures are appearing to discontinue the insertion mag meter and manufacturing appears to be leaning towards the doppler meter. Meter technology is rapidly improving and costs are dropping. Current cost for supply and installation of a insertion doppler meter is estimated to be $2,200.

Investigation and testing of open channel flow meters has shown that the broad crested weir has the best potential for turnout flow

measurement when used in conjunction with a data logger. Current cost for supply and installation of a precast broad crested weir is estimated to be $2,500.

<u>Cost of District Flow Measurement</u>

The SMRID was selected for determining the costs of introducing district wide turnout flow measurement. The district serves 350,107 acres with approximately 3,500 individual farm turnouts. Block surveys of the SMRID indicate that approximately 50 percent of the farm turnouts must be metered with inline flow meters and the remainder with open channel flow meters. The capital cost of purchasing, installation, turnout changes at open channel flow meters, and internal accounting changes within the district is estimated to be $9,550,000 ($2,730 per turnout, $27 per acre). In addition to the capital cost the district would incur an annual cost for meter reading, additional billing costs, and annual maintenance costs associated with the flow meters. These costs are estimated to be $139,000 ($40 per turnout, $0.40 per acre).

<u>Consequences of Flow Measurement</u>

In municipal water systems it has been found that introduction of water meters and billing by usage results in substantial reduction in water consumption. This reduction has been traced to the elimination of casual spillage due to poor lawn watering practice, overwatering, no repair of faucet and toilet leaks etc. This contrasts sharply with on farm water usage for irrigation purposes. Application of water requires energy input for sprinkler irrigation or labour input were flood irrigation methods are used. Extra water application results in significant additional cost to the user and if overwatering occurs, spillage and runoff from the land results in erosion and flooding of downslope landowners. Typical irrigation practice results in little direct water waste due to the cost and liability consequences of improper water management. The majority of water loss or usage inefficiency is resulting from the inherent distribution system inefficiencies of open channel flow. Introduction of turnout flow metering will not likely result in reduction of water usage. In fact it may result in increased water application per acre if a greater economic return can be achieved from a higher application of water.

## CONCLUSIONS

The investigations and testing undertaken in this study lead to the following conclusions:

1. Farm turnout flow measurement is achievable if a combination of pipe flow meters and open channel flow meters are utilized.
2. Insertion doppler meters and insertion mag meters appear to be most feasible for farm turnout flow measurement where a pipe flow meter must be used.
3. Precast broad crested weirs with data loggers appear to be most feasible for farm turnout flow measurement where an open channel flow measurement device must be used.
4. The installed cost of a pipe flow meter is estimated to be $2,200.
5. The installed cost of a open channel flow meter with associated turnout changes is estimated to be $3,000.

6. The cost of installing farm turnout flow meters for the SMRID is estimated to be $9,550,000 ($27 per acre).
7. The annual cost of billing by volume for the SMRID is estimated to be $139,000 ($0.40 per acre).
8. Introduction of farm turnout flow measurement will not likely decrease on farm water usage.
9. Introduction of further distribution system flow measurement and use of this information to regulate lateral spill flows can significantly reduce district spill flows and result in increased system efficiency.

# APPLICATION EFFICIENCIES OF LINEAR IRRIGATORS IN SOUTHERN ALBERTA

V. Ellert, D. Coutts[1]

## INTRODUCTION

The purpose of this study was to obtain accurate application efficiency data applicable to Southern Alberta conditions. In the process of designing sprinkler systems the application efficiency is required in order to calculate the required system capacity. In water management the application efficiency is used to determine how much water to apply.

The validity of the application efficiency numbers currently used is questionable. The numbers currently used originated from studies done several years ago when sprinkler technology was different than it is today. Many of the studies of application efficiency have been done under zero wind conditions. Due to the frequent occurrence of wind in southern Alberta, irrigating in the wind is unavoidable.

Although this study involved linear systems, the application efficiency data is generally applicable to pivot systems. In order to improve irrigation system design and water management practices, a reliable application efficiency number is required.

## METHODOLOGY

Testing was conducted under three separate machines in the St. Mary's River Irrigation District, near Bow Island. Irrigations were scheduled and conducted by the farmers.

Net application depth was measured with one litre oil cans. The cans were attached to surveyor's lath, at a uniform height, in an effort to avoid interference from the crop. Two lines of cans were placed in each field parallel to the lateral pipe with 4 metres between the rows. Cans were spaced 4 metres apart within the rows. A total of 100 cans were used at each site.

The average of the depths of water collected in these cans was considered the net application. The collected water was measured as soon as possible (usually immediately) following the irrigation to eliminate the need for evaporation correction.

Gross application was calculated by dividing the total system flow during the test by the area covered during the irrigation. System flow rate was measured with a pitot tube type differential velocity head flow meter. Machine travel rate was calculated by measuring the time it took the machine to travel a measured distance. The effective wetted length of the lateral was measured. The machine timer percentage setting was recorded.

Other data collected included; wind speed, wind direction, atmospheric temperature, cloud cover, and system operating pressure.

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[1] Irrigation Branch, Irrigation and Resource Management Division, Alberta Agriculture, Lethbridge and Bow Island, Alberta.

## RESULTS

Due to problems with data collection, and the very small number of tests completed in 1991, results are not reported here. Collection of the net application amount was successful.

The calculation of gross application presented two major problems:

1) An adequate length of straight pipe in the vicinity of the pumping unit was not available to meet the requirements of the flow meter available in the 1991 season. The flow measurements obtained were not reliable.

2) The measurement of the travel rate of the machines produced inconsistent results. Only one speed measurement was taken for each irrigation. This did not prove adequate. The machine travel rate appears to vary considerable for any given timer setting.

These two factors contributed to unreliable gross application results. This resulted in calculated application efficiencies in excess of 100% on some of the tests.

## SUMMARY AND CONCLUSIONS

The importance of accurate application efficiency numbers was highlighted by the extremely wide variation of results obtained in 1991. The unusually wet season prevented the completion of a significant number of tests. It is advised that this study be continued for several years in order to obtain accurate information.

# 1991 EVALUATION OF ALTERNATE SPRINKLERS FOR SIDEROLL SYSTEMS

V. Ellert, R. Hohm[1]

## INTRODUCTION

This study was carried out to evaluate the usefullness of low angle sprinklers on side-roll sprinkler systems. Due to the frequent occurrence of wind in Southern Alberta it is impossible for farmers to avoid irrigating under windy conditions. When sprinkler irrigation is used under windy conditions, much of the water is lost due to wind drift and high evaporation.

In the past ten years several new designs of sprinklers have been applied to center pivots. These new designs have been successful in reducing wind drift and operating pressures. In contrast, sprinklers used on side-roll systems have remained unchanged since the introduction of side-rolls to Alberta. Approximately 500,000 acres are irrigated with side roll systems in Alberta.

Lower angle sprinklers have the potential of reducing wind drift. Lower angle sprinklers produce a smaller radius of throw than standard high angle sprinklers. The objective of this study was to determine what affect lower angle sprinklers have on soil moisture levels. Specific questions that this study addressed are:

1. Does the use of lower angle sprinklers result in a greater amount of moisture entering the root zone?
2. Are the radius of throw produced by low angle sprinklers adequate?

## METHODOLOGY

Standard sprinklers typically have a 23 degree angle of trajectory. The sprinkler selected for evaluation against the standard sprinkler was a Weather-Tec 10-30L with a 15 degree trajectory. This sprinkler met the following criteria which the authors established as requirements for alternative sprinklers:

- Discharge of at least 12.5 GPM at a pressure of 45 PSI.
- Minimum radius of throw of 40′ at 45 PSI.
- Net cost to the farmer must not exceed $20.00 per sprinkler.
- Must be compatible with common "Jensen Type" self-levelers used on side-roll systems.

A group of four of the selected sprinklers were installed on each of three separate systems. These sprinklers were compared to adjacent standard angle sprinklers. Pressure regulators were used on all sprinklers under evaluation. Due to availability, 50 PSI regulators were used. All sprinklers evaluated in this project were equipped with 7/32" X 1/8" standard brass nozzles. The sprinklers were set up as detailed in figure #1.

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The systems were located in the Magrath, Taber and Lethbridge Northern Irrigation Districts. All sites were cropped to permanent forage.

Neutron probe access tubes were installed according to figure #1. The group of access tubes was designed so that the center tube was the maximum distance possible from the sprinklers. Groups of tubes were located under both the low angle sprinklers and adjacent standard sprinklers.

Soil moisture readings were taken before and after each irrigation. An irrigation consisted of the lateral operating on both sides of the group of access tubes. The systems were operated by the owners under normal conditions for one full irrigation season. Sprinkler nozzle pressures were monitored with a pitot tube.

The seasonal soil moisture levels under the two types of sprinklers were compared in order to evaluate the sprinklers. Wind speed was recorded using on-site totalizing anemometers. Wind speeds in Table #1, are averages for the duration of the irrigation, a period of at least 16 hours.

## RESULTS

A summary of the results is presented in Table #1. Note that data should only be compared between sprinklers within each test, the amount of water applied, wind, temperature etc. varied between tests. The unusually wet growing season prevented the completion of the planned number of tests. The data from the Taber site was not usable due to irregular lateral positions during the irrigations.

Specfic results are as follows:

1. In all tests the lower angle sprinkler resulted in a greater amount of moisture entering the root zone as compared to the neighboring standard sprinkler. The difference in average additional soil moisture varied from 9.5 to 40.0 (mm of moisture per metre). This demonstrates that the low angle sprinkler resulted in a higher application efficiency than the standard angle sprinkler.

2. Data for the center tube relates to the effective radius of throw of the sprinkler. If the effective radius of throw is inadequate, readings for this tube will be lower than the average. In all tests the center tube reading was greater for the low angle sprinkler. The low angle sprinkler resulted in a center tube reading from 4.5 to 66.7 (mm of moisture per metre) greater than the center tube reading under the standard sprinkler. This indicates that the radius of throw for the low angle sprinkler was better than the standard sprinkler.

3. The last column of data in Table #1 represents the variance between the minimum and the maximum tube readings. This is a measure of the uniformity of the soil moisture. This data indicates that the low angle sprinkler resulted in more uniform soil moisture levels.

## SUMMARY AND CONCLUSIONS

The lower angle sprinkler tested has potential to increase the application efficiency of side roll systems under windy conditions. Further evaluation of this sprinkler is recommended. Due to the

difficulty in working in field conditions, it is recommended that further testing involve single sprinkler testing in accordance with ASAE standard S330.1.

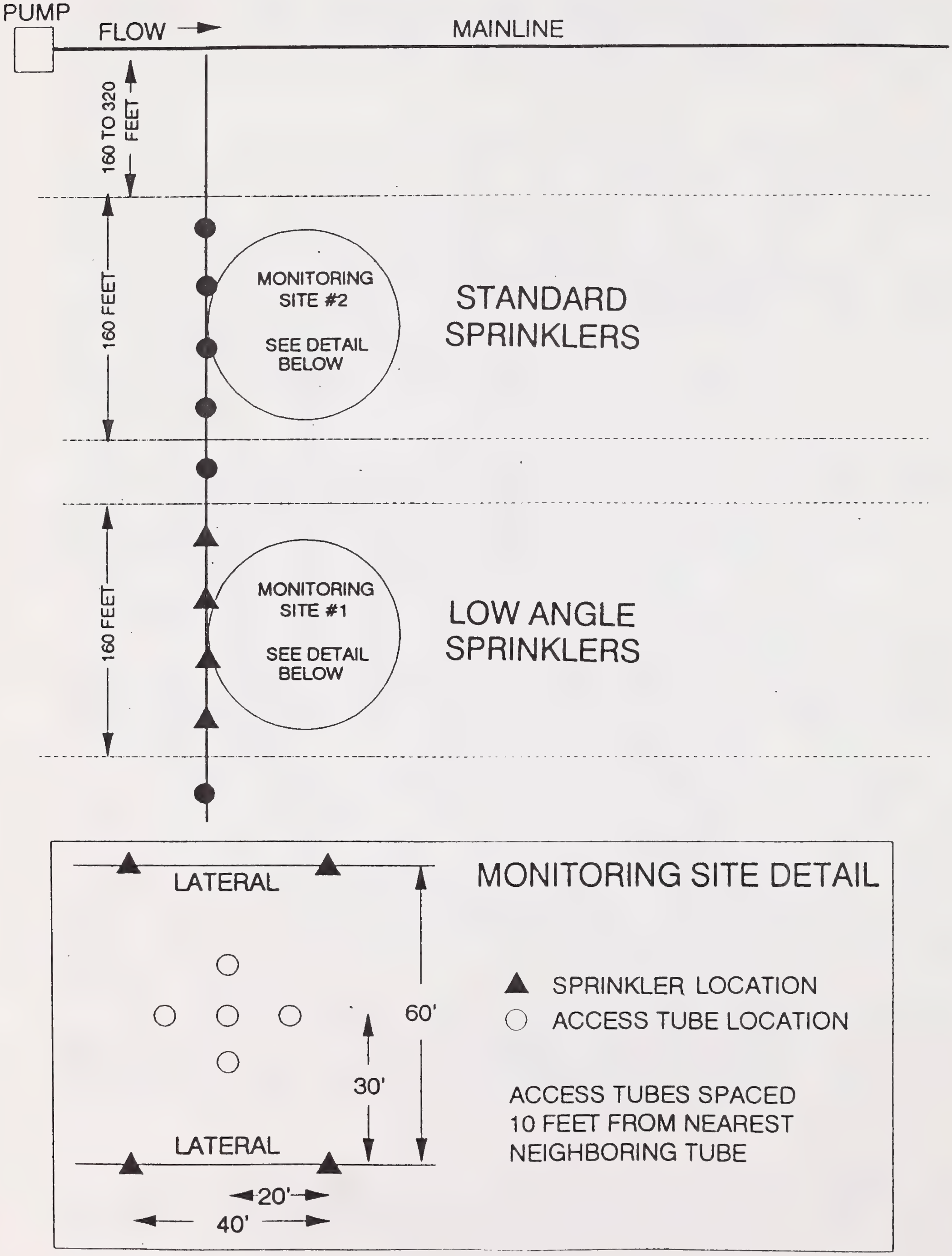
Alberta Agriculture would like to acknowledge the co-operation of the farmers involved. This project would not of been possible without the use of the farmer's systems and their assistance.

TABLE #1: SUMMARY OF ALTERNATE SPRINKLER RESULTS

This table compares the amount of moisture that was added to the root zone, as measured with a neutron soil moisture probe.

| | | | | <-------- MOISTURE ADDITION TO ROOT ZONE (mm per metre) --------> | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | WIND | | | | | | | | | | |
| TEST NO. | DATE | SPEED (km/hr) | SPRINK ANGLE | <- INDIVIDUAL ACCESS TUBE DATA --> NORTH | SOUTH | EAST | WEST | CENTER | < DATA FOR ALL TUBES > MINIMUM | MAX. | AVERAGE | MAXIMUM VARIANCE |
| HOHM 1 | 05 27 | 8.5 | HIGH | 32.2 | 9.0 | 26.5 | 50.4 | 32.5 | 9.0 | 50.4 | 30.1 | 41.4 |
| | | | LOW | 35.2 | 48.3 | 44.0 | 35.0 | 37.0 | 35.0 | 48.3 | 39.9 | 13.3 |
| HOHM 2 | 07 17 | 20.4 | HIGH | -7.6 | -5.3 | 20.0 | 16.7 | -2.3 | -7.6 | 20.0 | 4.3 | 27.6 |
| | | | LOW | 14.0 | 10.4 | 21.2 | 16.6 | 6.7 | 6.7 | 21.2 | 13.8 | 14.5 |
| HOHM 3 | 08 09 | 8.8 | HIGH | 61.9 | N/A | 62.4 | 55.9 | 26.3 | 26.3 | 62.4 | 51.6 | 36.1 |
| | | | LOW | 76.0 | 95.8 | 101.3 | 92.1 | 93.0 | 76.0 | 101.3 | 91.6 | 25.3 |
| HOHM 4 | 08 30 | 12.1 | HIGH | -1.0 | N/A | 4.5 | 10.5 | -1.8 | -1.8 | 10.5 | 3.1 | 12.3 |
| | | | LOW | 21.2 | 12.2 | 22.5 | 17 | 12.8 | 12.2 | 22.5 | 17.1 | 10.3 |
| GENESIS 1 | 05 22 | 11.3 | HIGH | 59.3 | 104.9 | 76.9 | 77.0 | 70.8 | 59.3 | 104.9 | 77.8 | 45.6 |
| | | | LOW | 86.7 | 118.6 | 103.2 | 83.2 | 104.5 | 83.2 | 118.6 | 99.2 | 35.4 |
| GENESIS 2 | 06 08 | 37.8 | HIGH | 33.1 | 17.2 | 34.7 | 22.4 | 32.5 | 17.2 | 34.7 | 28.0 | 17.5 |
| | | | LOW | 37.8 | 47.6 | 44.2 | 54.6 | 46.5 | 37.8 | 54.6 | 46.1 | 16.8 |

FIGURE 1 - FIELD PLAN
ALTERNATE SPRINKLER DEMONSTRATION 1991



# DEMONSTRATION OF FLEXIBLE GATED PIPE FOR SURFACE IRRIGATION

M. Rigby[1]

## INTRODUCTION

At present, the relatively low cost of water delivered by irrigation districts provides little economic incentive for surface irrigators to increase their overall irrigation efficiency. There is, however, concern over maintaining and improving the production capabilities of irrigated land. This includes reducing deep percolation and salinity problems generated by seepage from head ditches used in supplying water to surface irrigated fields. Controlling deep percolation also has the secondary advantage of improving surface irrigation efficiency. Irrigation efficiency may be further increased by reducing evaporation from open ditches, thereby diminishing in-field conveyance losses.

Water can be conserved and soil degradation prevented by replacing open head ditches with a pipeline. In this manner, evaporation and seepage losses may be significantly reduced. An added benefit to producers in supplying water via a pipeline is the lower labour requirement when compared with traditional methods. Unfortunately, the high capital cost associated with aluminum gated pipe has discouraged many surface irrigators from upgrading their mode of operation. Offering a low cost alternative could favour head ditch replacement.

In the mid-1970's, vinyl tubing equipped with plastic gates was developed for water conveyance purposes. Limitations included low allowable operating pressure and limited life expectancy (Kruse et al., 1980). This project was undertaken to assess the performance of flexible gated pipe as a means of supplying water to surface irrigated land. Soil moisture was monitored along border dykes in order to evaluate distribution differences between dykes irrigated by gated pipe and those irrigated by conventional open ditch.

## METHODS

During the summer of 1991, a flexible gated pipe demonstration project was installed on a machine levelled, surface irrigated field situated 12 kilometers north of Vauxhall. Border dykes were spaced 15 meters apart with an average downfield slope of 0.1 percent. A 400 meter long head ditch located along the west boundary of the field was replaced with 457 mm diameter, 10 mil thick, flexible gated pipe (Poly Pipe*) donated by Armin Plastics. Installation involved clamping one end of the pipe to a steel culvert and unravelling it into a shallow trench formed by filling in and resurfacing the existing ditch. The pipe was partially filled with water and sliding, plastic gates (donated by Hutchinson Wil-Rich Manufacturing) were inserted with a hole-punch device at a spacing of approximately two meters along the entire length of the pipe. The original head ditch was left intact to supply water to the last two border dykes.

* Trade names are presented for information purposes only and do not constitute an endorsement of a particular product or manufacturer.

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[1] Irrigation Branch, Irrigation and Resource Management Division, Alberta Agriculture, Box 588, Vauxhall, Alberta, TOK 2K0.

Nuclear depth moisture gauge access tubes were installed down the centre of two adjacent border dykes irrigated by Poly Pipe (GP) and two irrigated by open ditch (OD). Access tubes were located at a distance of 2 meters west and 2, 50, 100, 200, 400 and 800 meters east of the pipe/ditch (Figure 1). The two treatments, GP and OD, were separated by an unmonitored, Poly Pipe irrigated border dyke.

A system discharge of 113.6 litres/second (1800 US gpm) was used to irrigate the alfalfa crop twice during the growing season, once in the second week of June and again in mid-July. Soil texture was determined to be predominantly sandy loam with evidence of a greater proportion of clay and silt particles at lower depths. Soil moisture readings were taken at 0.30, 0.60, 0.90 and 1.20 meter depths on eleven dates between May 13 and September 4, 1991.

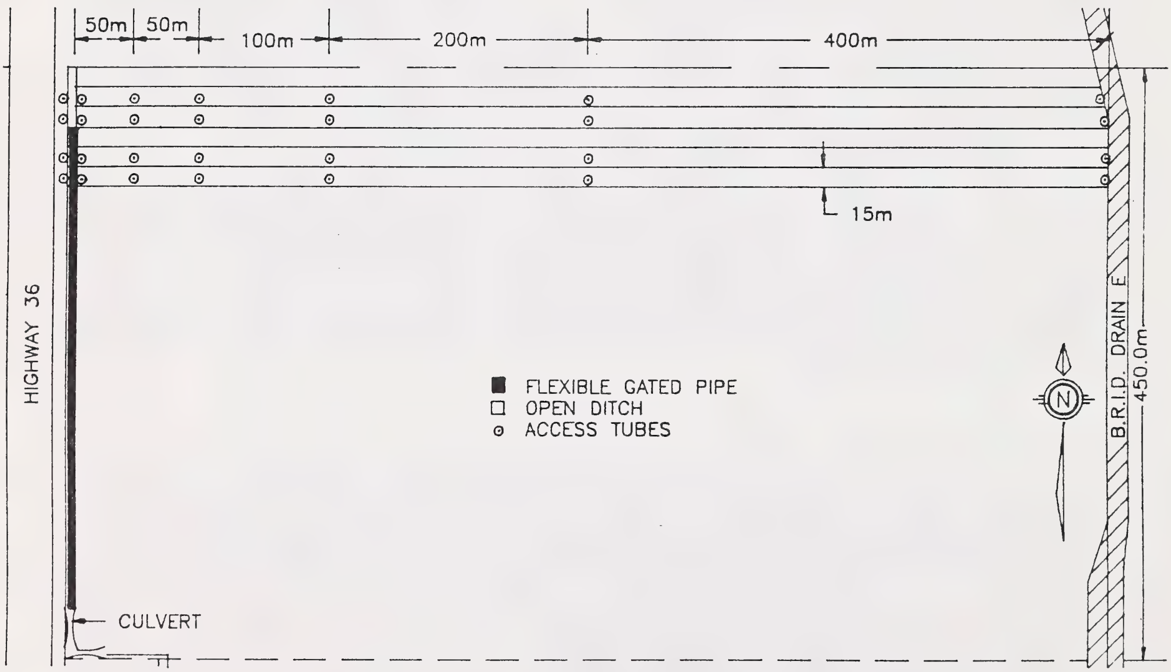


**Figure 1:** Field lay-out for flexible gated pipe demonstration project.

## RESULTS AND DISCUSSION

Preliminary results suggest that soil moisture was slightly lower in dykes irrigated by gated pipe than those operated by open head ditch. Soil moisture was combined for all depths at each access tube location and averaged for both dykes in each treatment. Figure 2 indicates that the largest treatment difference in post-irrigation soil mositure occurred at the top end of the field. Treatment effects appeared to decrease as the distance from the open ditch/gated pipe reached 400 meters. It is likely that head ditch seepage contributed, at least in part, to the higher soil moisture experienced under the open ditch treatment when compared with gated pipe. Unfortunately, water in the bottom of access tubes located two meters west of the supply line prevented monitoring post-irrigation seepage at the upstream location.

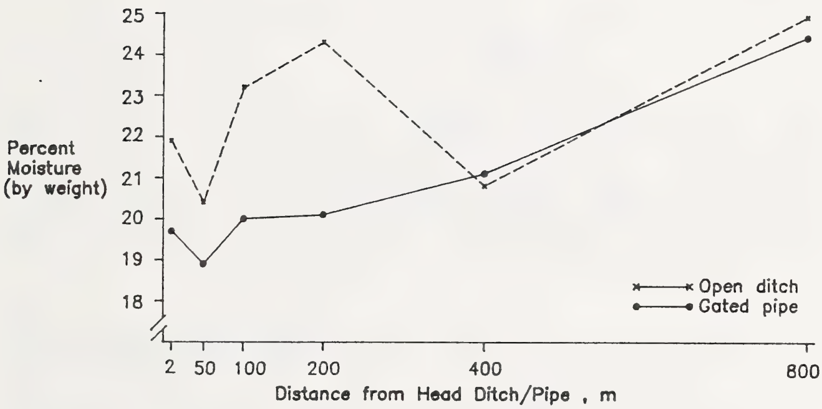


**Figure 2:** Post-irrigation soil moisture distribution.

When all sampling dates were combined to produce a seasonal average, OD soil moisture was only 0.1%, 0.5%, 1.0% and 0.9% higher than GP at depths of 0.30, 0.60, 0.90 and 1.20 meters, respectively (Table 1). Frequent rain showers during the sampling season may have influenced results by masking treatment effects.

Table 1: Average seasonal soil moisture for all test hole locations combined.

| Depth (m) | Percent soil moisture (by weight) OD | GP |
|---|---|---|
| 0.00-0.30 | 11.5 | 11.4 |
| 0.30-0.60 | 19.0 | 18.5 |
| 0.60-0.90 | 22.8 | 21.8 |
| 0.90-1.20 | 25.3 | 24.4 |

On average, soil moisture appeared to be adequate for crop production. Assuming a sandy loam soil in the upper root zone with a heavier soil in the lower root zone, field capacity would likely range between 15% and 25%. This compares favourably with results tabulated above although, in certain specific incidences, soil moisture may have been excessive at depths greater than 0.90 meters.

## SUMMARY

Flexible gated pipe showed some promise as a means of controlling supply ditch seepage and possibly eliminating evaporation from open ditches. Post-irrigation soil moisture seemed to be lower on dykes irrigated by gated pipe than those operated by open head ditch. Differences in seasonal soil moisture were minimal although moisture was slightly greater for open ditch treatments than gated pipe, at all sampled depths.

Plans are to continue with this project in the upcoming summer. The economic viability of flexible gated pipe will be estimated by determining the expected lifespan of the material when exposed to southern Alberta's weather conditions. In 1992, an attempt will be made to evaluate temporal differences in soil moisture by increasing the intensity of monitoring immediately prior to, and after, each irrigation event.

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# DISCHARGE VARIABILITY IN POROUS RUBBER TRICKLE IRRIGATION TUBING*

D. Roll[1]

## INTRODUCTION

Porous rubber trickle irrigation tubing is used in a variety of applications where line source subsurface irrigation laterals are required. Installation guidelines are provided by manufacturers but little information is available on the hydraulic performance and discharge variability of this this material. Such information would be useful in designing systems with this material. One criteria of trickle emitter performance is the coefficient of manufacturing variation, CV (ASAE 1988), which gives a statistical evaluation of the variation in discharge due to manufacturing among equal units of the component (emitters or lengths of lateral tubing). Coefficient of variation is expressed as:

$$CV = s/q_{av}$$

where
CV = coefficient of manufacturing variation (a dimensionless value)
qav = mean discharge (L/h) at constant pressure and temperature of emitters in the sample.
s = standard deviation of the discharge (L/h) of the emitters in the sample

$$s = \left[ \frac{\sum_{i=1}^{n} (x_i - q_{av})^2}{n-1} \right]^{1/2}$$

where
xi = the discharge of an emitter
n = the number of emitters

For this statistical evaluation to be relevant, the data must follow a normal distribution whereby 68% of the observed discharge values are within one standard deviation of the mean, 95% are within two standard deviations, and all values are within three standard deviations of the mean. Various studies (Clemmens 1987, Madramootoo et. al. 1987, Boman 1988) have been completed to determine CV for point source emitters, but none of the literature indicates similar evaluations for this material, a line source emitter. The objective of this study was to determine the line discharge from equal lengths of tubing at five pressures and to calculate the coefficients

* Trade names mentioned are to identify the particular product used and do not imply preferential endorsement.

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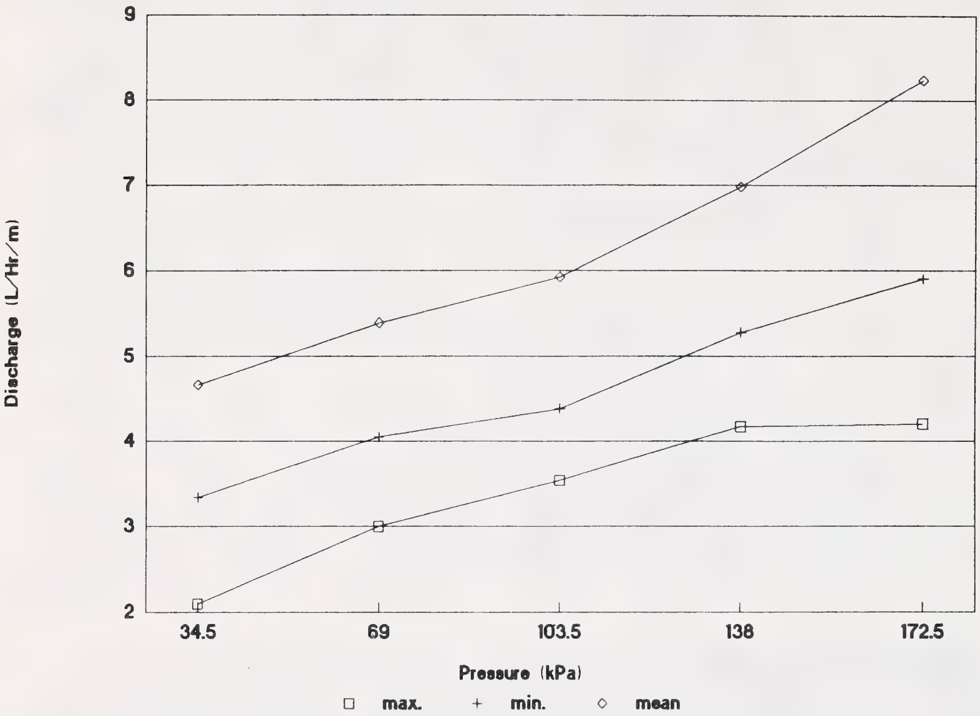
of manufacturing variation, CV, for each pressure. The resulting CV values indicate the discharge sensitivity to pressure. Low CV values indicate greater uniformity of discharge among the samples tested and hence less discharge variation due to manufacturing of the component.

Figure 1. Discharge from porous rubber trickle tubing at various pressures




## MATERIALS AND METHODS

Three 1m lengths of 6mm I.D. Leaky Pipe" porous rubber tubing were selected at random, connected to a water source in a laboratory, and their ends sealed. Constant pressures of 34.5, 69, 103.5, 138, and 172.5 kPa were maintained using an adjustable pressure regulator monitored by a pressure gauge at the discharge side of the regulator. Water source pressure was 469 kPa with momentary fluctuations between 345 kPa and 552 kPa. Discharge from each tube was collected and measured every 2 hours for a period of 8 hours at each pressure setting. Lengths of 38mm dia. PE tubing were placed over the rubber tubing to collect the discharge from each section. Discharges were collected in a plastic container and measured using a graduated cylinder. For each tube, four measurements were recorded for each pressure. Water temperature was noted.

## RESULTS AND DISCUSSION

### Tubing discharge

Mean discharge for the unit lengths of tubing are shown in Figure 1. Discharge increased in a linear relationship to increased pressure, with mean values ranging from 3.3 L/hr/m at 34.5 kPa to 5.9 L/hr/m at 172.5 kPa. It was observed that the mean rate of discharge decreased with time and approached a constant rate after 8 hours (Figure 2).

Figure 2. Decrease in mean discharge rate during test period.

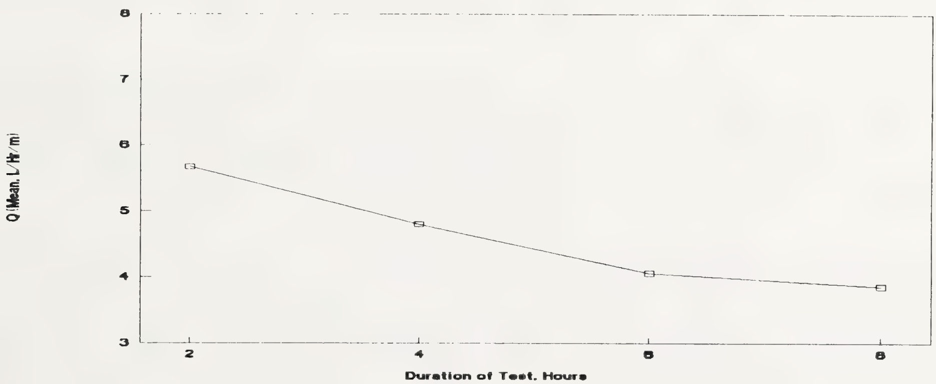
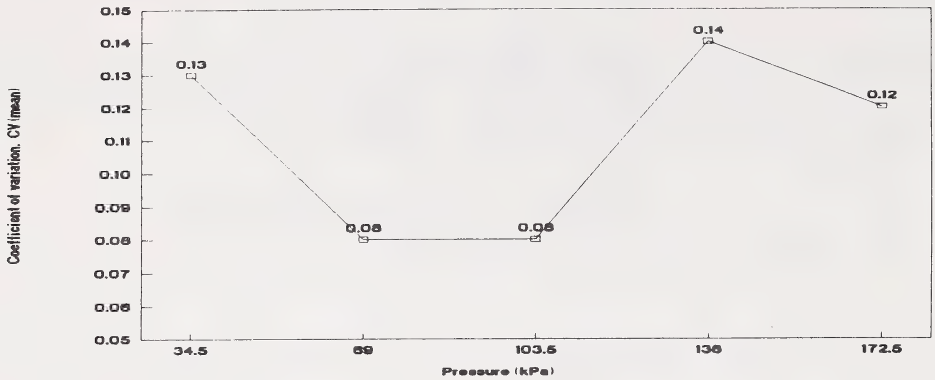



Table 1. ASAE classification of manufacturer's coefficient of variation, CV, for line source emitters.

| CV | ASAE Classification |
|---|---|
| < 0.10 | good |
| 0.10 - 0.20 | average |
| > 0.20 | marginal to unacceptable |

Figure 3. Coefficient of variation, CV, for 6mm porous rubber tubing at five operating pressures, 0 - 8 hour period.




It is not known why this occurred under constant operating pressure. Water temperature remained at 18°C after one hour, from an initial temperature of 23°C. It is possible that the tubing material may swell during operation, decreasing its porosity, and simultaneously the discharge through the tubing wall.

Coefficient of variation due to manufacturing

An interpretive classification of the coefficient of variation due to manufacturing is shown in Table 1. For each pressure, CV values were calculated using equation (1) and discharge data obtained for each two hour period. The mean values were then plotted against pressure (Figure 3). Discharge values followed a nearly normal distribution (67 % of all discharge values for each pressure were within one standard deviation of the mean), for 69 to 172.5 kPa inclusive. Values for 34.5 kPa did not follow a normal distribution. As shown in Figure 3, the CV values were lowest for 69 and 103.5 kPa, indicating that the variability of discharge among the three 1m tubes was lowest at these operating pressures. Referring to the classification in Table 1, good CV's were obtained at 69 and 103.5 kPa, and average values at all other test pressures.

## SUMMARY

The CV values calculated indicate that good uniformity of discharge can be expected from equal lengths of randomly selected tubing when operated between 69 and 103.5 kPa. In this investigation an operating time of 8 or more hours was required for discharge rates to stabilize, and it was significantly lower than the initial rate of discharge. Further investigation using a greater number of tubes would provide more data and therefore greater confidence in the statistical analysis. Further study with a flow regulated water source and substantially greater lengths of tubing are required to determine if decreases in discharge rates during operation are a result of the tubing material or to flow variations in the water supply.

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# LISTING FOR EMERGENCY WIND EROSION CONTROL

J. Timmermans and C. Sprout[1]

## INTRODUCTION

Maintaining adequate crop or residue cover is the best way to prevent wind erosion of soil. In situations where the soil is left in highly erodible condition, faces high potential of erosion or is actively eroding, it is necessary to carry out emergency controls. One type of emergency control is listing of the field with lister shovels at right angles to the prevailing erosive winds. In the fall of 1990, listing was carried out on a 50 ha field near Mossleigh, which had virtually no residue cover, and was actively and seriously eroding. The listed field was monitored over winter to observe the effectiveness of this emergency control method.

## METHODS

The land in question (S1/2-35-20-25-W4) was a fallow field where low soil moisture had prevented proper emergence of fall-seeded winter wheat. The soil was an eroded dark brown chernozem, sandy loam in texture, developed on locally sorted glacial till. The topography was gently rolling. Erosion had already occurred to the extent that the roadside ditch on the east side of the field was full and soil was drifting across the road. Three rows of straw bales had been placed across the more severely eroded east end of the field, but this provided very little erosion control on such a large field.

Listing was carried out in October of 1990 using lister shovels mounted on the back gang of a heavy duty cultivator. The ridges were about 90 cm across, 23 to 30 cm deep, and were orientated north-south. The prevailing erosive winds are from the west. The shovels used were 12 and 15 inch shovels commonly used in irrigated potato production. The field was revisited for observation two or three times a month until spring.

## RESULTS AND DISCUSSION

No evidence of drifting was observed until November 30, 1990. Strong winds from the west in the latter part of November and first part of December caused significant drifting on the east (more erodible) side of the field and onto the road. The furrows here were filled to a large extent while the rest of the field had about 10 cm of loose soil in the furrows.

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[1] Soil Conservation Section, Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, Bag Service #1 Airdrie, Alberta T4B 2C1.

The latter part of December brought strong winds from the north. The winds blew along the furrows and deposited some of the loose soil into the stubble field to the south (Figure 1). By this time the furrows on the east were full and soil had drifted across the road again. From January to the end of March there was no evidence of further erosion.

Listing creates ridges to reduce the proportion of the soil surface exposed to the wind. The ridges disrupt the airflow over the surface, and trap soil particles dislodged by wind erosion in the furrows. This stops the cumulative destructive nature of wind erosion, but only until the furrows are filled to the point where this trapping effect is again reduced.

## CONCLUSIONS

Listing the field did not stop soil erosion but it was very effective in reducing the extent of soil loss on most of the field. The ridges effectively trapped drifting soil in the furrows. The exception was when strong winds from the north blew down the furrows. This shows that the orientation of the ridges to the prevailing erosive winds is critical to the overall effectiveness of this emergency control method. The listing was not as effective on the east side of the field due to virtual lack of any soil aggregation. The ridges here trapped moving soil which would otherwise have left the field, but they should have been re-formed once or twice during the winter to spring seasons.

The observations made of this study suggest that listing is particularly suited to sandy soils which allow deep tillage by the lister shovels.

Figure 1. Furrows in listed field have reduced erosion losses by trapping moving soil. (March 15, 1991 photo)

# SOIL LOSS AND RUNOFF FROM SELECTED CONSERVATION AND CONVENTIONAL SUMMERFALLOW PRACTICES

S. Nolan, K. Skarberg and T. Goddard[1]

## INTRODUCTION

There is a lack of data and understanding of the effects of management practices on soil erosion by water. Difficulties with studying erosion include the unpredictability of rainstorms and the difficulty repeating them. Portable rainfall simulators enable the study of rainfall effects in undisturbed field conditions. An over view of the simulator study is presented in Nolan and Goddard (1991).

One of the reasons that summerfallow is practiced on the Prairies is to increase moisture reserves in the soil. However, traditional summerfallow practices leave the soil in a condition that is vulnerable to water erosion. Conservation summerfallow is practiced to reduce soil erosion as well as to reduce runoff, leading to enhanced moisture conservation. The objective of this study was to measure runoff and soil loss and runoff from conventional and conservation methods of summmerfallow using a rainfall simulator.

## METHODS

The rainfall simulator delivers water under pressure to a static, solid cone pattern nozzle at 0.8 - 1.2 m centered over a 1.0 $m^2$ study plot. Nozzle diameter, pressure output and height from the soil surface are manipulated to achieve the desired rainfall intensity as described in Tossell et al., (1987). The simulations in this study were conducted at intensities of 60 and 140 mm/h for 20 minutes. Sites were not pre-wet prior to the rainfall simulations.

A 1 m x 1 m frame was driven into the ground so that each study plot was fully contained. A collection trough was attached to the frame to allow sediment and water (runoff) to move off of the plot during the simulation and be drawn into sample bottles by suction. Subsamples of runoff were collected for 0.5 to 1 minute every 3 minutes during each 20 minute simulation. Total runoff was also collected throughout the simulation and amounts were determined by weight. Amounts of sediment in the runoff (soil loss) were determined by oven drying and then weighing.

Treatments were characterized on the basis of soil moisture, bulk density, surface texture and per cent residue cover. The characterization and rainfall simulation measurements were repeated three times for each treatment over a 1 to 2 day period.

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[1] Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, 206, 7000 - 113 Street, Edmonton, Alberta, T6H 5T6.

Sites were selected which had management comparisons on similar soil types (within a site) and slopes of 5 per cent. One site was located on a Black loamy sand north of Mundare and was a Stanislaw Sandblasters demonstration of conventional and chemfallow management practices. The previous crop had been wheat (1989). The rainfall simulation was conducted on April 30, 1991 using a light intensity of 60 mm/h. Another site was located on a Brown loam south of Skiff and was a South Forty Conservation Club demonstration of conventional tillage summerfallow, bladed fallow and chemfallow. The previous crop was also wheat (1990). The simulation took place on August 20 and 21, 1991 using a heavy intensity of 140 mm/h.

## RESULTS AND DISCUSSION

The results from both the Mundare and Skiff sites are similar, though the data were collected from sites with different conditions (soil types, seasons and simulated rainfall rates). There were no significant differences (P=0.1) between moisture levels for any of the treatments at a site. Bulk density was significantly different at Mundare only, where the conventional value was 1.1 and the chemfallow was 1.4 $g/cm^3$. Surface residue cover was 17 and 97 % for the conventional and chemfallow at Mundare, and 12, 65 and 47 % for the conventional, chemfallow and bladed treatments, respectively at Skiff.

At both sites, total soil loss and total runoff after the simulation were greater from the conventional than from the chemfallow treatment. All differences in soil loss from chemfallow and conventional treatments were statistically significant (P=0.1). Average total soil and runoff losses are presented in Figures 1 and 3 in an indexed form where soil loss and runoff from the conventional treatment were assigned a value of 100. All other values were indexed relative to the conventional fallow amounts. The standard error is represented by error bars.

Figures 2 and 4 represent rates of runoff and soil loss using logarithmic regressions about the three repetitions per treatment. The slopes of the soil loss and runoff curves are much steeper for the conventional than for the conservation fallow, indicating higher rates of soil and runoff losses. Though runoff start times were significantly later for the conventional fallow than for chemfallow at both sites, this did not act to reduce total amounts of soil loss. The amount of simulated rainfall that is not running off of the plots is infiltrating into them. In all cases, the conservation fallow treatments show increased infiltration over the conventional fallow.

Total soil loss from the conventional fallow at Mundare was significantly greater and over 4 times the soil loss from the chemfallow (Figure 1). Total runoff from the conventional fallow was also significantly greater and more than four times as high as that from the chemfallow.

At Skiff, the total soil loss from the conventional fallow was 11 and 17 times greater than from the bladed and chemfallow treatments,

respectively (Figure 3). The difference between soil loss from the conventional and conservation treatments was significant, but that between the chemfallow and bladed fallow was not significant.

Total runoff from the bladed fallow at Skiff was 2 times less than from the conventional (significant at P=0.1), but there was no difference in runoff from the chemfallow and conventional. The similarities between the conventional and the chemfallow may be due to the reduced roughness of the chemfallow relative to the conventional treatment and possibly to its reduced cover relative to the chemfallow treatment at Mundare.

Figure 4a) illustrates the slopes of the curve for runoff from the three treatments at Skiff and indicates that, inversely, the bladed fallow treatment had the greatest amount of infiltration. The soil loss curve is flattest for the chemfallow treatment, (Figure 4b) despite its runoff, indicating that increased runoff may not be directly proportional to soil loss.

## SUMMARY AND CONCLUSIONS

A rainfall simulator was used to evaluate the effect of conservation and conventional methods of summerfallow on runoff and soil loss. Conditions on a Black sandy soil (near Mundare) were evaluated in the spring and on a Brown loam soil (near Skiff) in the fall. In all cases, the least amount of runoff was from the conservation treatments, resulting in increased infiltration. At both sites, soil loss from the conventional summerfallow practice was significantly greater than from the chemfallow practice (from 4 to 17 times greater). This appeared to be the case regardless of the magnitude of the runoff. Wide-bladed summerfallow also significantly reduced soil loss when compared with conventional fallow (practice present only at the Skiff site). There was no difference in soil loss between the bladed and chemfallow treatments.

## ACKNOWLEDGEMENTS

The following people have been very helpful with this study. Conservation and Development Branch staff: Germar Lohstraeter, Desiree Jans, Guerrillmo Recinos-Diaz. County of Forty Mile: Shawn Geiger. Producers: Bill Darichuck, and Howard Hutchinson.

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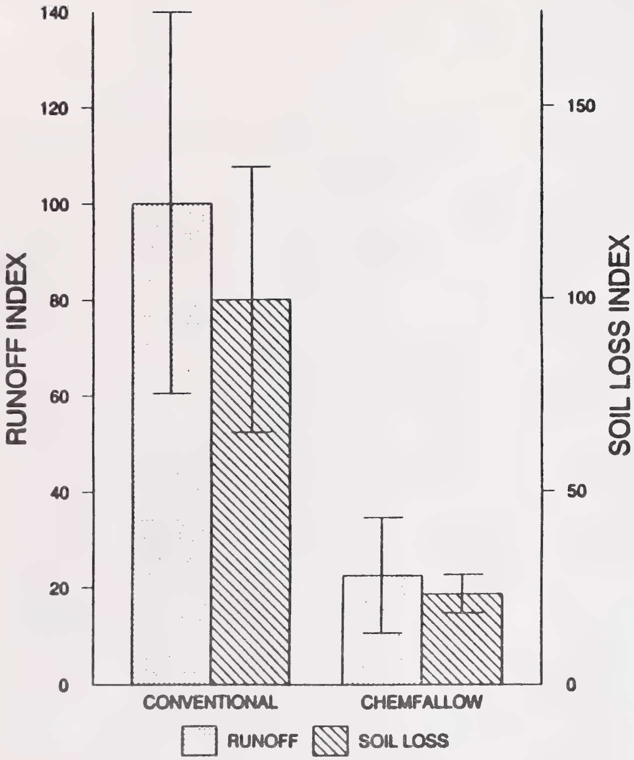


**Figure 1:** Total runoff and soil loss from summerfallow at Mundare (Black sandy soil, spring conditions, rainfall simulation intensity at 60 mm/h for 20 minute duration).

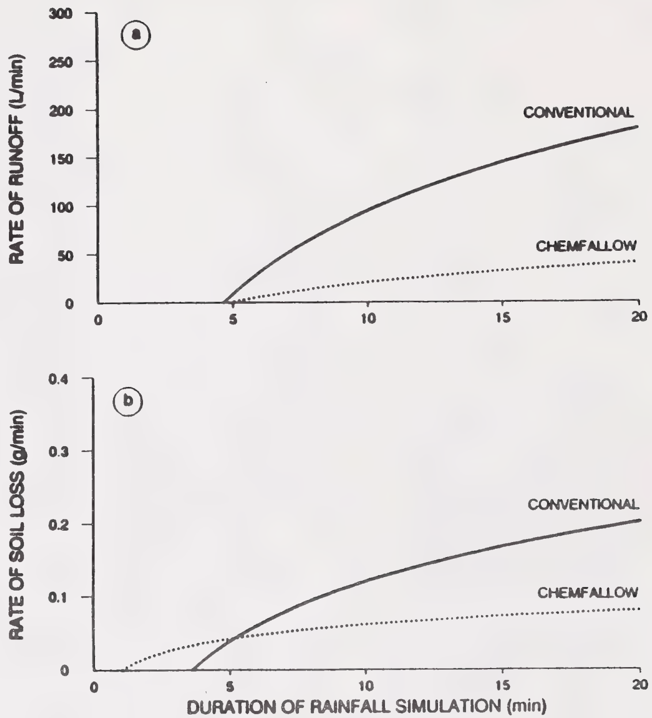


**Figure 2:** Runoff rate (a) and soil loss rate (b) from summerfallow at Mundare (Black sandy soil, spring conditions, 60 mm/h intensity).

NOTE: Since lines are averages, the origins of the soil loss lines may appear ahead of the runoff lines.

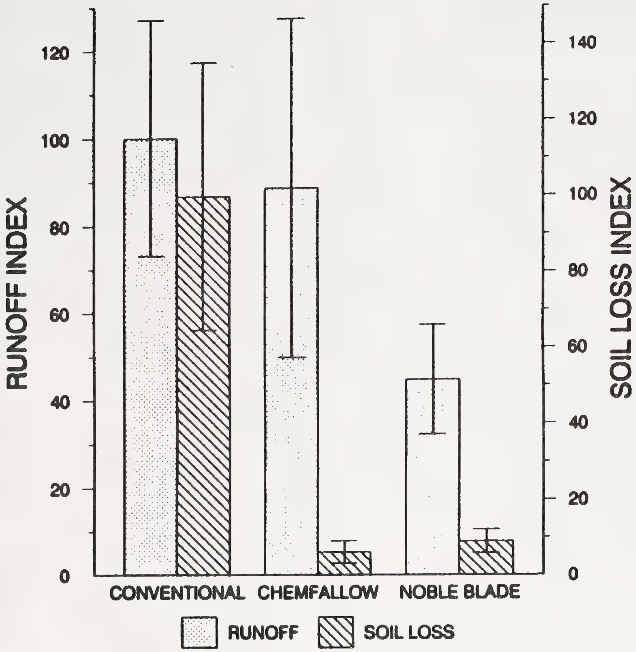


**Figure 3:** Total runoff and soil loss from summerfallow at Skiff (Brown loam soil, fall conditions, rainfall simulation intensity at 60 mm/h for 20 minute duration).

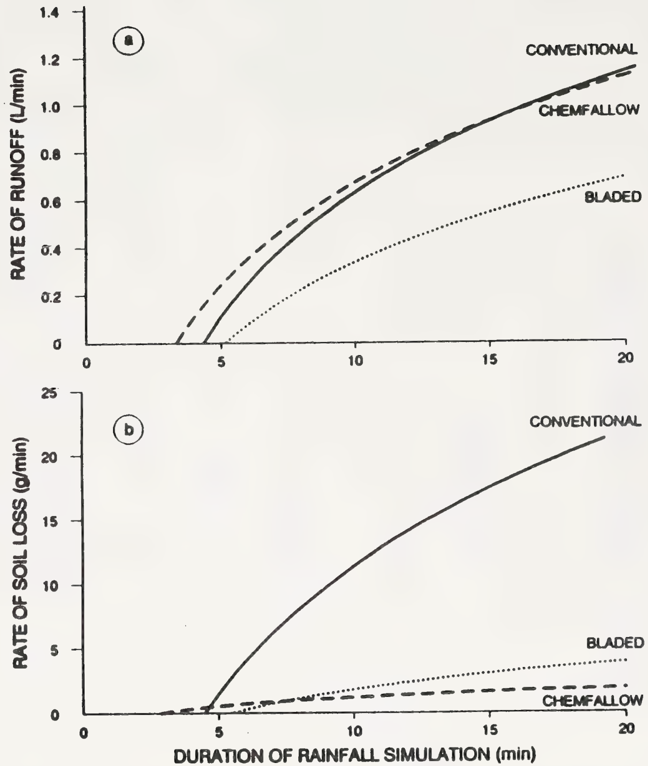


**Figure 4:** Runoff rate (a) and soil loss rate (b) from summerfallow at Skiff (Brown loam soil, fall conditions, 140 mm/h intensity).

NOTE: Since lines are averages, the origins of the soil loss lines may appear ahead of the runoff lines.

# HYDROLOGY AND SOIL SALINIZATION NEAR CROSSFIELD, ALBERTA 1990-1991

B. Read and D. Wentz[1]

## INTRODUCTION

The seasonal dynamics of the hydrology and geochemistry of a saline seep was studied at a test site near Crossfield, Alberta in 1990. The project continued in 1991 during which time vegetative measures were implemented to control soil salinity. Results of this study will ascertain the effect of vegetative controls on hydrology and geochemistry associated with soil salinization.

## METHODS

The saline seep chosen for this investigation is located on the V. Machacek farm (SE 26-28-28 W4), just east of the town of Crossfield (Figure 1). Four sites located in a transect perpendicular to the topographic gradient, from the bedrock ridge to the saline seeps at the lower slope positions, were selected for soil, hydrological and geochemical investigations (Figures 2). Sites 1831 and 1832 are saline seeps located at lower slope positions, site 1833 is located at the middle slope position and site 1834 is located at the upper slope position of the bedrock ridge (Figure 3).

Site characterization, instrumentation, data collection and sampling criteria are described in the interim report of this title (Miller and Read 1990).

In May of 1991, an alfalfa-grass mixture (Beaver Alfalfa and Pubescent Wheatgrass) was seeded as a soil salinity vegetative control, in a 180 m wide strip running 800 m north-south along the east edge of the quarter (14.4 ha).

## RESULTS

Hydrological and chemical information collected from the two saline sites (1831, 1832) over the two years of this study are presented below.

### Site 1831

Shallow groundwater and surface discharge were the primary causes of soil salinity at site 1831. Major precipitation events and snowmelt runoff were the contributing sources of surface water discharge into the region of the seep at site 1831 (Figures 4 and 5). Seasonal precipitation from April through September of each year (1990, 339mm; 1991, 323mm) was similar to the thirty year mean (330mm).

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[1] Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, Agriculture Centre, Lethbridge, Alberta, T1J 4C7.

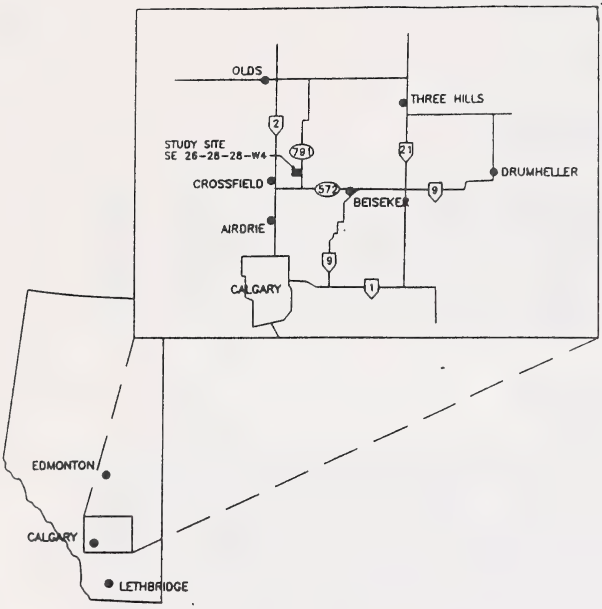


**Figure 1. Study site location.**

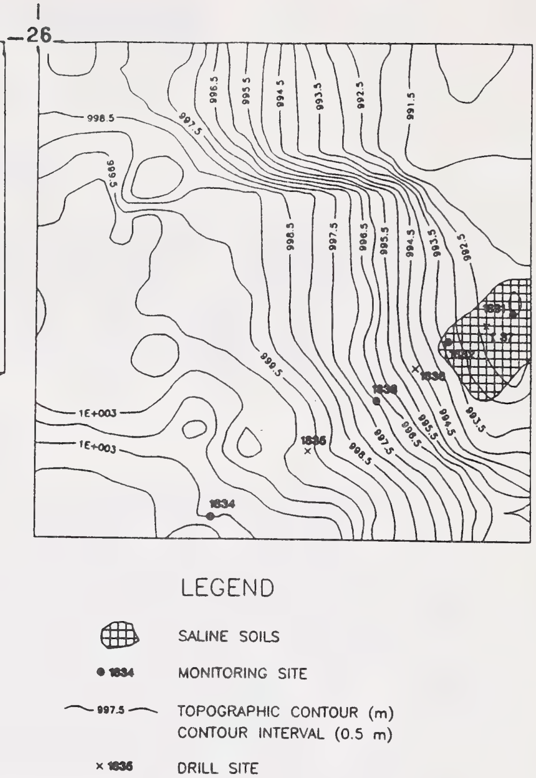


**Figure 2. Monitoring locations.**

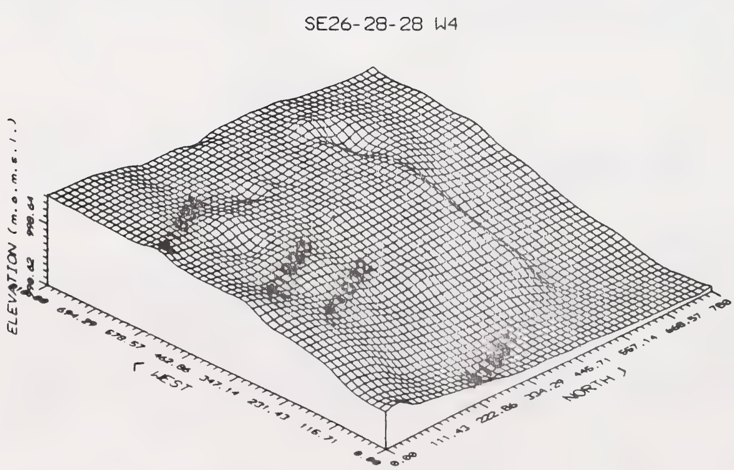


**Figure 3. 3-D topographic representation.**

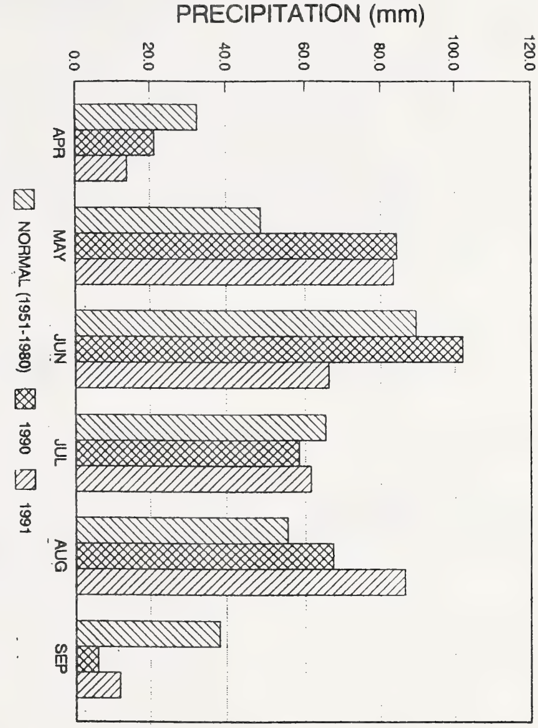


Figure 4. Seasonal precipitation 1990, 1991 (30 year mean.)

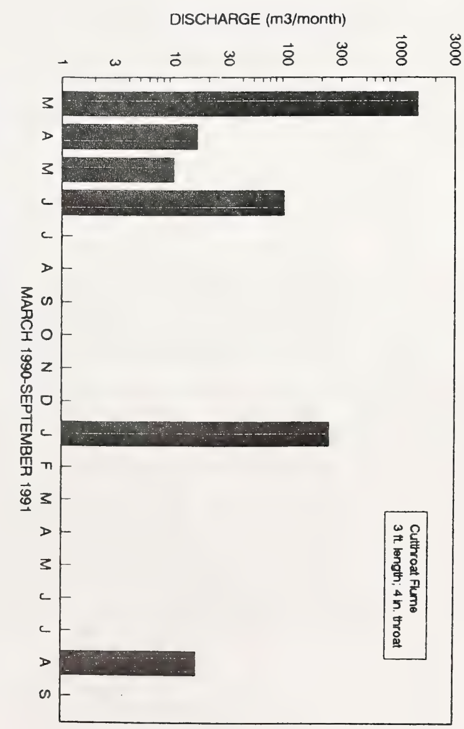


Figure 5.Seasonal surface discharge 1990-1991.

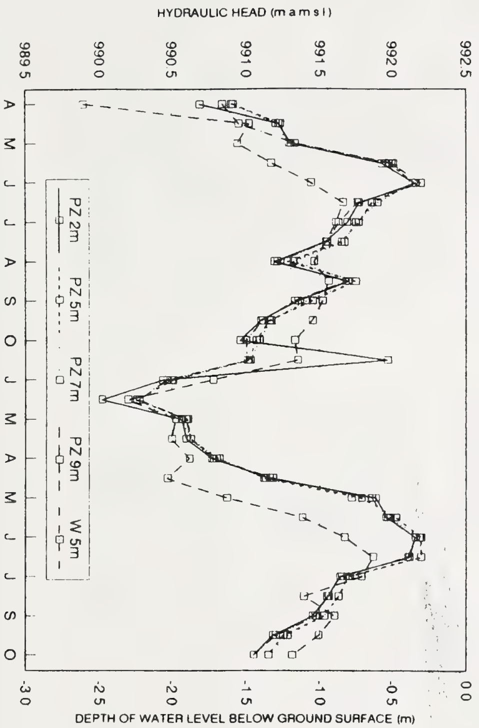


FIGURE 6. SITE 1831

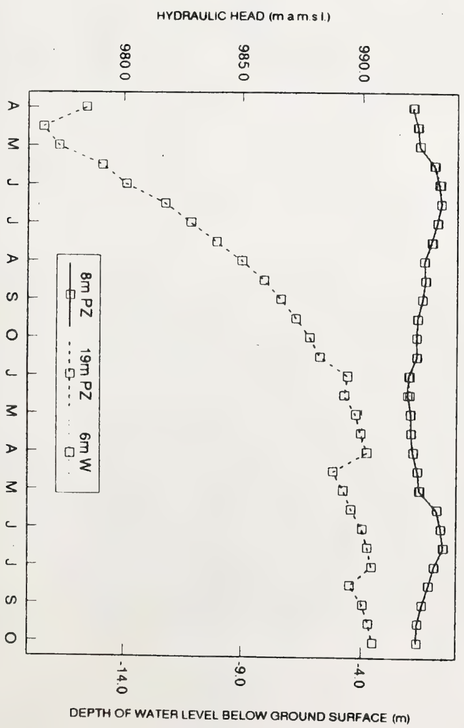


FIGURE 7. SITE 1832

Groundwater levels at this site were comparable in 1990 and 1991, with the most shallow depth occuring in the June-July period (0.26m, 1990) and the deepest levels recorded in the spring (2.70m, 1991) (Figure 6).

Groundwater electrical conductivity in the 5m, 7m and 9m piezometers were static and similar over the two seasons with a mean value of 6.3 dS/cm. The 2m pz showed a slight increase over time, ranging from a low of 14.4 dS/cm in 1990 to a high of 16.2 dS/cm in 1991. The EC of the groundwater in the 5m water table well showed the largest decline in salinity, dropping from a high of 15.6 dS/cm in 1990 to a low of 8.39 dS/cm in 1991.

Soil electrical conductivity generally declined over the two years throughout the 30 to 150 cm depth. Surface soils (0-30 cm) exhibited a decline in EC through 1990 (14.8-10.3 dS/cm) but climbed through the winter and spring of 1991 to a high of 16.0 dS/cm. There was an overall increase in surface soil EC at this site.

Site 1832

This site was also a saline seep, however, because of its position upslope from 1831, it was not influenced by surface water discharge. Groundwater levels at this site in the 6m well and 8m piezometer, fluctuated from most shallow in the summer to deepest over winter (0.83-2.50m). It was not until the spring of 1991 when the water levels in the 19m pz finally recovered from initial hydraulic conductivity bail tests in 1990, that equilibrium conditions were reached. From that point on, water levels in that pz were relatively stable (Figure 7).

Water well EC showed a steady decline over the two year period from a high in 1990 (3.49 dS/cm) to a low in 1991 (2.29 dS/cm). The EC of the groundwater in the piezometers showed only minor fluctuations and was relatively steady at 3.2 dS/cm in the 8m pz and 3.5 dS/cm in the 19m pz.

Soil electrical conductivity at this site showed seasonal fluctuations, that is, lowest values at each depth were recorded in mid summer, with levels rising to a mid winter peak then gradually declining again. There was no significant improvement in soil salinity at site 1832, in fact, surface soil showed an overall increase over the two years.

## CONCLUSION

It was intended that the implementation of vegetative controls would intercept and consumptively use shallow groundwater moving downslope and would also use surface water which was contributing to an increase in the groundwater table. This would ultimately lower water tables and reduce the groundwater contribution to soil salinization at sites 1831 and 1832. Since the implementation of the alfalfa-grass mix in May of 1991, there has been no obvious decline in groundwater levels or in the electrical conductivity of the soil. It was not expected, though, that changes would be apparent at this early date, since in its first season, alfalfa only roots to a maximum depth of about 1.2m (Dodds 1985). Mean water table depth at site 1831 from the time of seeding until the fall of 1991 was 1.49m and 1.67m at site 1832. In both cases, water tables were below the maximum rooting depth of alfalfa at that

stage and it is unlikely that the alfalfa has had any influence on the water table depth at this point.

Monitoring of hydrological and geochemical parameters will continue in 1992. At that time, deeper rooting and increased moisture use by the alfalfa should result in a draw down of the groundwater table with a subsequent reduction in soil EC.

In addition, a multi-year project was initiated at this study site in 1991. The National Soil Conservation Program (NSCP), will monitor and predict soil salinity based on data collected at this and other NSCP sites across the prairies. At site 1831 is located is a totally automated climate station which collects meteorological parameters to be used in this project.

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# SOIL TILTH AS AFFECTED BY ORGANIC MATTER AND SODICITY INTERACTIONS

B. Read and D. Wentz[1]

## INTRODUCTION

Water infiltration rate, aggregate size and germination rate are all manifestations of soil tilth. These processes are adversely affected as soil sodium increases and as organic matter decreases. Increasing sodium and decreasing organic matter promotes soil dispersion and crusting. The relative impact of sodium adsorption ratios (SAR's) and organic content has not been assessed. This information is essential for predicting water movement into sodic soils (for cropping and reclamation applications), and also for water quality assessment.

The intent of this study was to determine how organic matter and sodicity impact soil tilth. High sodium levels in soils which are low in organic content frequently result in the establishment of a poor seedbed. It is possible that the low organic content is as much a limiting factor for soil tilth as are high sodium levels. If this is the case, good soil tilth might be attained when an optimal balance between sodium and organic matter exists.

## METHODS

In preparation for hydraulic conductivity, aggregate stability and germination rate tests, surface soil (0 - 25 cm deep) samples were collected from the four Alberta soil zones (grey-wooded, black, brown, and dark brown). Three sites within each zone were sampled in order to attain a range in soil textures (fine, medium and coarse).

Field texturing and laboratory particle-size analysis was conducted on each sample collected to determine soil texture. Each sample was initially sieved through a 2 mm screen. Individual samples were mixed in a cement mixer, so that homogeneity in organic matter and soil aggregate distribution throughout each soil could be achieved.

Chemical profiles were determined for each soil. This information was used to derive $Na_2SO_4$ amounts required to amend each soil to sodium adsorption (SAR) levels of approximately 4, 9, 16 and 32. Organic carbon content was also determined.

Control samples prepared for all analyses consisted of non-amended soils. SAR determination was based on 100g samples. To amend smaller and larger sized testing samples, the $Na_2SO_4$ required was adjusted appropriately.

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# RESULTS

In order to conduct this experiment, the following assumptions were made:

1. Organic carbon is an indicator of soil organic matter.
2. Sodium adsorption ratio is an indicator of soil sodicity .
3. Hydraulic conductivity (HC), aggregate stability (AS) and germination rate (GR) are relative functions of soil tilth.

Assessment of soil tilth can therefore be performed by regressing HC, AS and GR against the two major components of soil tilth in question, that being SAR and organic matter. The premise being, the higher the correlation coefficient the greater the influence on soil tilth.

Initially, data were grouped for regression analysis into the three major catagories (HC, AS and GR) regardless of soil zone or texture. Comparison of each group with SAR and OC indicated the lack of any significant relationship. This suggested that other factors such as soil texture and soil type may influence the interactions of sodicity and organic matter on soil tilth. As such, data were grouped more specifically according to textural groups (coarse, medium and fine), soil zones (grey-wooded, black, brown and dark brown) and combinations of each. This approach yielded more significant correlations.

## Regressions

The first relationship examined was the effect which the SAR has on aggregate stability. The method used to measure aggregate stability was the mean weight diameter (MWD). MWD was compared with the SAR on a soil textural basis. Correlation coefficents for this comparison were generally poor with $r^2$ values of 0.16 for coarse soils, 0.49 for medium textured soil and 0.26 for fine textured soil. Similarily, when SAR and aggregate stability are compared on a soil zone basis the relationships are once again poor, that is, 0.18 in the brown soils, 0.19 in the dark brown, 0.28 in the grey-wooded and 0.35 in the black soils.

Organic matter, presented as percent organic carbon, did not compare well with mean weight diameter on a textural basis. The $r^2$ values ranged from 0.04 in the fine textured soil to 0.41 in the medium. On a soil zone basis the relationship improved somewhat. The correlation coefficient in the grey-wooded soil was 0.25, 0.39 in the black, 0.48 in the brown and in the dark brown soils, 0.80.

The second variable, germination rate (GR), was also compared individually with the SAR and the organic carbon. On a textural basis, the SAR and GR compared very well, that is, $r^2$=0.52 in medium textured soils, 0.93 in fine soils and 0.99 in the coarse soil. The same was true on a soil zone basis where SAR versus GR yielded correlation coefficients of 0.86, 0.90, 0.95 and 0.97 in grey-wooded, dark brown, brown and black soils respectively.

When organic carbon was compared to germination rate according to texture, the relationship was mixed. Specifically, 0.03 in coarse soils, 0.22 in fine soils and 0.77 in the medium. Coefficients were wide ranging when regressing OC versus GR according to soil zone. The brown and black soils compared well, 0.88 and 0.91. The dark brown and grey-wooded soils compared poorly, 0.01 and 0.05.

The hydraulic conductivity (HC), was the final function of soil tilth to be examined. SAR versus HC when grouped according to texture generally compared well. In fine and medium textured soil, coefficients

were 0.91 and 0.89 respectively, but only 0.41 in the coarse soil. Soil zone groupings yielded a wide range of correlations. The best relationships for SAR versus HC were in the brown, 0.95, and dark brown soils, 0.80. The poorest relationships were found in grey-wooded, 0.05 and black soils, 0.36.

The organic carbon, hydraulic conductivity comparisons on a textural basis did not reveal any significant relationships. Coefficients were generally poor with medium textured soil the highest at 0.58, fine soils next at 0.35 and coarse textured soil the worst at 0.30. OC versus HC according to soil zone related very well with values of 0.99, 0.93 and 0.91 respectively.

Trends

Best fit curves were plotted in conjuction with each regression performed in order to determine the degree to which trends existed within each relationship. The following conclusions were made.

SAR: The SAR did not appear to have a significant influence on the stability of the aggregates when the comparisons were made on a textural and on a soil basis. Even though the correlation coefficients were low there was a trend for the MWD of the aggregates to increase slightly with an increase in SAR.

Germination rates and SAR's did compare well, with coefficients generally high in most instances. More specifically, SAR had an adverse affect on germination rates with rates declining dramatically as SAR's increased. This is especially true in this case for alfalfa which is a moderately salt tolerant crop.

Hydraulic conductivity showed a direct response to changes in the SAR. Increasing the SAR resulted in a decline in the HC. These results were consistent whether the regressions were performed on data grouped texturally or according to soil zone.

Organic Matter: In every instance where regressions were performed between organic matter and AS, HC or GR on data grouped either texturally or zonally, there was no consistency in the directional slope of the line. When comparing OC vs AS, the stability of the aggregates generally decreased as organic matter increased, except in medium textured soil. The same is true for soil zone data, except in the brown and dark brown soils.

Inconsistencies were present for OC - HC relationships also. Here, HC declined with an increase in organic matter, with the exception of medium soils, grey-wooded and dark brown soils.

Finally, germination rates increased with an increase in organic matter except in coarse soils. The reverse was true according to soil zones where germination rates generally declined with increasing organic matter, except in the brown soils.

In every instance when SAR was compared with either AS, HC or GR the plotted linear functions displayed consistent trends for each of the three textures or four zones. On the other hand, when OC was compared with AS, HC or GR, in every case there were exceptions to the directional slope of the line. For example, as organic carbon levels increase, hydraulic conductivity decreases,except in medium textured soil; or, as organic carbon levels increase, germination rates decrease, except in brown soils. These inconsistencies make prediction of trends difficult and further highlight the lesser effect which organic matter may have on the functions of soil tilth.

Figure 1 presents the overall influence of each variable on tilth from combined data on either a soil textural or soil zone basis.

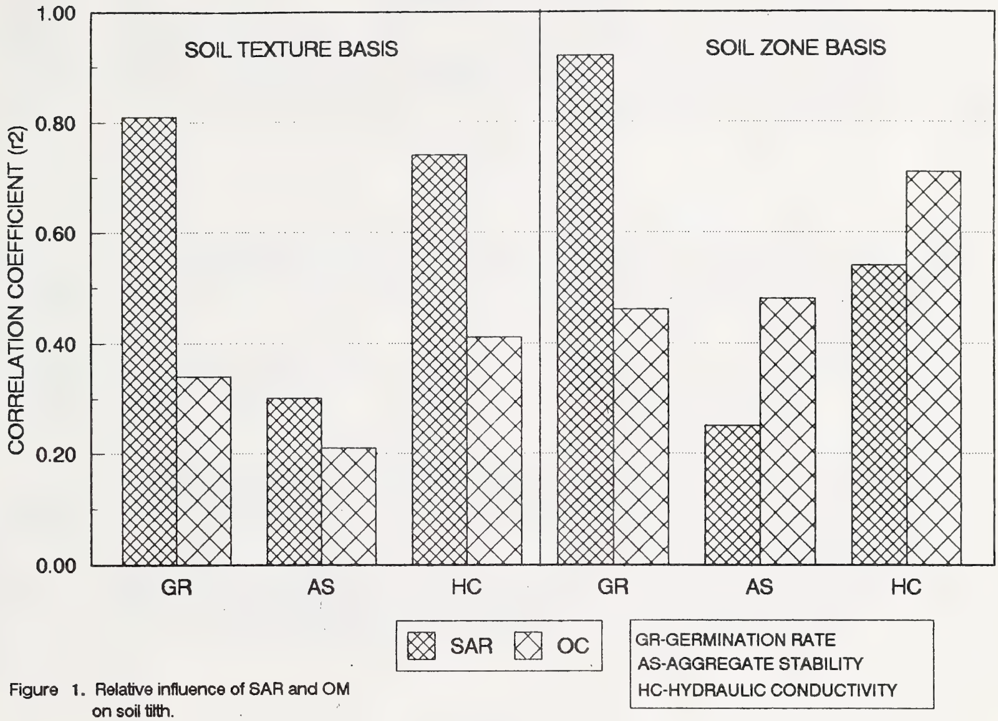


Figure 1. Relative influence of SAR and OM on soil tilth.

## CONCLUSIONS

Sodicity appears to have a greater influence on soil tilth than does organic matter if the relative influence of each is examined on a soil textural basis. In fact, mean coefficients for SAR regressions were nearly double those for similar OC regressions, that being 0.62 and 0.32.

On soil zone grouped data, mean coefficients were almost identical for SAR and OC regressions, 0.57 and 0.55. This suggests that neither organic matter nor sodicity exerts more influence on soil tilth than the other, when based on soil zone data alone.

Overall, the mean correlation coefficient from all SAR grouped regressions was 0.59; from organic carbon, the $r^2$ was 0.44.

While the SAR of the soil was amended to provide a wide range of sodicity, the organic matter content was unaltered and remained at a level characteristic of the soil zone from which it was sampled. Mean organic carbon percentage ranged from 1.19 in the brown soils to 2.31 in the black (dark brown 1.71% and grey-wooded 1.67%). Amending soils to higher levels of OM may have influenced the exchange complex in the soil because of the increase in the number of negatively charged OM particles (Henry 1987). This would affect the HC and AS, possibly improving the outcome of the OC regression analysis.

It was expected that the organic content of the soil was a major contributing factor to soil tilth. While organic matter at the levels studied was found to influence the various functions of tilth, it was not as influential as was soil sodicity. Increasing soil organic content improves soil tilth, but decreasing soil sodicity may serve to improve tilth to a greater degree. The latter is not as easily accomplished, however. On a field scale it may simpler to amend organic matter than SAR. Therefore, while SAR may have a greater impact on soil tilth, organic matter may have the most practical influence.

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# ROOTING DEPTH AND MOISTURE USE OF EIGHT SALT-TOLERANT GRASSES (Interim Report)

B. Read, C. Livergood and D. Wentz[1]

## INTRODUCTION

The control of dryland saline seepage requires in part, the management of subsurface water. To this end, high moisture use, deep-rooted perennials such as alfalfa are recommended as the primary crop on dominant recharge areas, that is, the areas immediately adjacent and upslope of the saline seep. A project conducted by the Conservation and Development Branch of Alberta Agriculture added to the existing data base by determining which varieties of alfalfa are best suited for this purpose (Miller and Read 1990). This information aids in the recommendation of particular alfalfa varieties for seepage control based on rooting depth, moisture use and yield.

Cropping in the more saline discharge area of a saline seep requires a more salt-tolerant crop, most commonly a grass variety. Information on rooting depth and moisture use of salt-tolerant grasses, though, is not as readily available for local environmental conditions. The opportunity to determine this information was taken in coordination with an existing Farming for the Future "Salt Tolerant Grass Variety Demo".

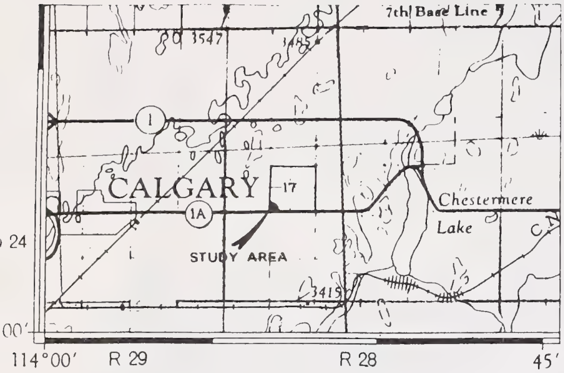
## METHODS

The study site is located in the south-west quarter of section 17-24-28 W4 (Figure 1). The plot area itself is contained within an eight hectare parcel of moderately saline land with a mean root zone electrical conductivity of 4.5 dS/cm.

Twenty-four, fifteen square metre plots were established consisting of eight grass varieties randomized and replicated three times (Figure 2). The eight grass varieties used were as follows:

| | | |
|---|---|---|
| Russian Wildrye | (RWR) | Puccinellia Alkali Grass (PAG) |
| Tall Wheatgrass | (TWG) | Pubescent Wheatgrass (PWG) |
| Altai Wildrye | (AWR) | Reed Canary Grass (RCG) |
| Garrison Creeping Foxtail | (GCF) | Slender Wheatgrass (SWG) |

[1] Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, Agriculture Centre, Lethbridge, Alberta, T1J 4C7.




re 1. Study area.

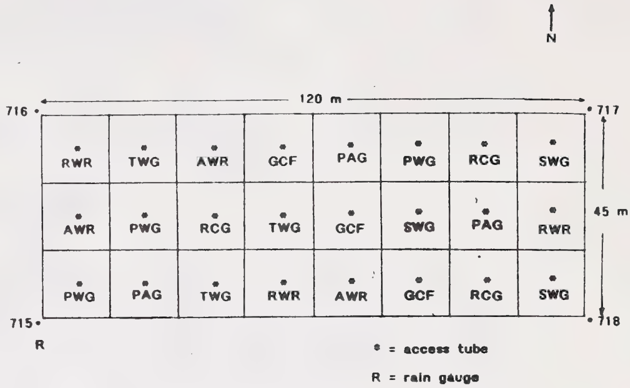



Figure 2. Experimental design.

Following an intensive seed bed preparation in early May, each grass variety was seeded at recommended field rate (AFCAC 1987) to a depth of two cm with a 15 cm row spacing. Each variety was fertilized with 17-20-0, broadcast at a rate of 180 kg/ha. To reduce the edge effect, the adjacent area immediately surrounding the plots was seeded to a salt-tolerant grass mixture.

Centrally located within each plot, a 1.2 m neutron access tube was installed to allow for the measurement of soil moisture. At each corner of the plot area a 4-5 m water well was installed to monitor groundwater movement. A rain gauge was set up on site to collect precipitation. All data was collected on a bi-weekly basis throughout the season (May - September 1991).

## RESULTS AND DISCUSSION

Year one of this study (1991) involved primarily the layout and instrumentation of the plots, and the seeding and establishment of the grasses. As is common with newly seeded grass, a weed problem developed (primarily kochia, wild oats and foxtail). To control this, the entire plot area was mowed on two separate occasions in July and sprayed once in August with the herbicide 2-4D amine.

Because weed growth throughout the plots was extensive, it was impossible to determine to what extent the moisture use measured in each plot was from the grass. In 1992 when the grasses are better established and the chemical control of the weeds has occurred, moisture use determination of each individual grass variety will be possible. At that time fallow plots will be established and seasonal moisture use curves plotting fallow versus cropped moisture use can then be graphed. Soil moisture consumption will be calculated from these graphs as the area between the grass and fallow curves. Rooting depth will be determined by the intersection of the two curves. Coring in each plot will allow for a visual determination of rooting depth and will serve to augment calculated values.

Groundwater was monitored on a routine basis to chart the influence that shallow groundwater may have on the soil moisture content within the root zone of the plots. Total rainfall (180 mm) was also measured throughout the season to determine the quanitity of water available to the crop from that source.

Seasonal soil moisture use for each grass variety (the mean of three replicates) was plotted (Example figures 3,4). The general trend in the moisture use curves at the 60, 90 and 120 cm depths suggests stable moisture levels throughout the season. At the 0-30 cm depth, where evapotranspiration is occuring, the soil moisture content shows a general decrease to seasons end, with only minor inflections in the curve as a result of precipitation. Even with appreciable rainfall being received in the latter part of the season, moisture use still decreased in surface soils as the grass and weeds became established and extracted more water. At the 60 cm depth, the curve shows to a lesser degree some late season signs of moisture depletion, suggesting deeper rooting and increased moisture use over time.

While the moisture extraction in these moderately saline plots is not exclusively by the grasses, there is still some early evidence of increased moisture use in those plots cropped to the more salt tolerant grasses. Table 1 lists in decending order the soil moisture use (vol. pct.) of each grass variety based on spring to fall net change. Grasses such as Tall Wheatgrass and Russion Wildrye which are generally considered very salt tolerant rank two and three among the highest moisture users while a low salt tolerant grass such as Reed Canary Grass ranks 8th in soil moisture use.

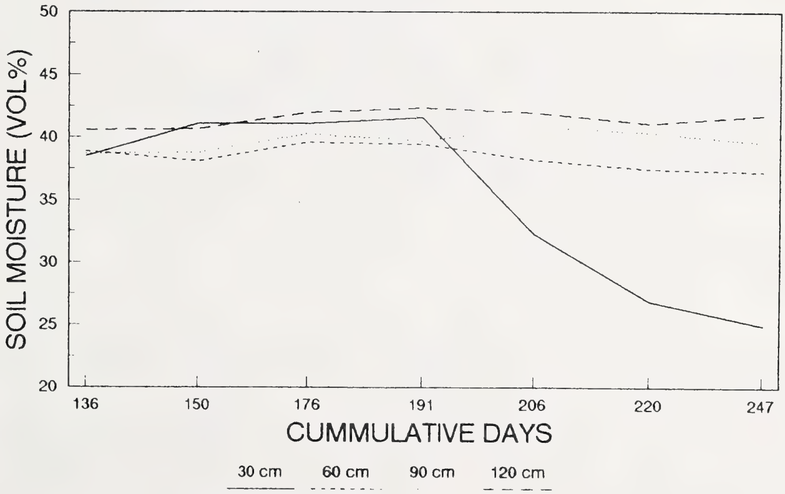



Figure 3. Seasonal soil moisture-Russian Wildrye.

## CONCLUSION

The ability of salt tolerant grasses to extract moisture from saline soils is indicated to a very limited degree in the early stages of this study. Generally, grasses considered the most salt tolerant were found in plots exhibiting the highest moisture use. The converse is true. As the grasses establish, rooting depth and moisture use will

increase and differences between varieties should become more evident. Year two of this project should provide more conclusive moisture use and rooting depth information for different grass varieties in saline soil.

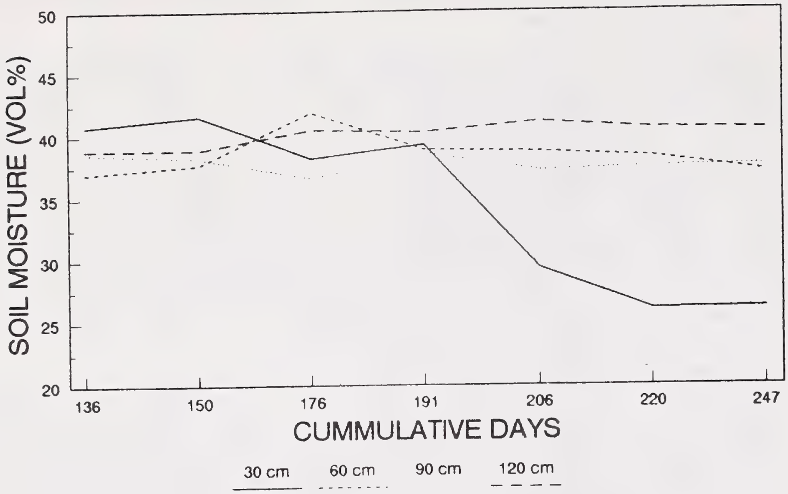



Figure 4. Seasonal soil moisture-Tall Wheatgrass.

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Table 1a. SEASONAL MOISTURE USE

| SOIL MOISTURE (VOL %) | | | | | | PUBESCENT WHEATGRASS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 cm | | | 60 cm | | | 90 cm | | | 120 cm | | |
| May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff |
| 38.6 | 25.7 | -12.9 | 36.7 | 33.8 | -2.9 | 38.9 | 37.0 | -1.9 | 39.1 | 39.4 | +0.3 |
| TOTAL SEASONAL USE (VOL %) -17.4 | | | | | | | | | | | |

| SOIL MOISTURE (VOL %) | | | | | | TALL WHEATGRASS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 cm | | | 60 cm | | | 90 cm | | | 120 cm | | |
| May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff |
| 40.8 | 26.2 | -14.6 | 37.0 | 37.1 | +0.1 | 38.6 | 37.6 | -1.0 | 38.9 | 40.5 | +1.6 |
| TOTAL SEASONAL USE (VOL %) -13.9 | | | | | | | | | | | |

| SOIL MOISTURE (VOL %) | | | | | | RUSSIAN WILDRYE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 cm | | | 60 cm | | | 90 cm | | | 120 cm | | |
| May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff |
| 38.5 | 25.0 | -13.5 | 38.9 | 37.3 | -1.6 | 38.7 | 39.6 | +0.9 | 40.6 | 41.8 | +1.2 |
| TOTAL SEASONAL USE (VOL %) -13.0 | | | | | | | | | | | |

| SOIL MOISTURE (VOL %) | | | | | | SLENDER WHEATGRASS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 cm | | | 60 cm | | | 90 cm | | | 120 cm | | |
| May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff |
| 33.2 | 27.3 | -5.9 | 34.5 | 28.1 | -6.4 | 35.8 | 33.7 | +2.1 | 36.4 | 37.9 | +1.5 |
| TOTAL SEASONAL USE (VOL %) -12.9 | | | | | | | | | | | |

| SOIL MOISTURE (VOL %) | | | | | | ALKALI GRASS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 cm | | | 60 cm | | | 90 cm | | | 120 cm | | |
| May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff |
| 36.2 | 26.0 | -10.2 | 39.0 | 37.0 | -2.0 | 37.5 | 38.1 | -0.6 | 39.4 | 38.4 | -1.0 |
| TOTAL SEASONAL USE (VOL %) -12.6 | | | | | | | | | | | |

| SOIL MOISTURE (VOL %) | | | | | | ALTAI WILDRYE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 cm | | | 60 cm | | | 90 cm | | | 120 cm | | |
| May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff |
| 40.1 | 27.8 | -12.3 | 38.2 | 36.7 | -1.5 | 37.7 | 38.3 | +0.6 | 39.7 | 41.3 | +1.6 |
| TOTAL SEASONAL USE (VOL %) -11.6 | | | | | | | | | | | |

| SOIL MOISTURE (VOL %) | | | | | | GARRISON CREEPING FOXTAIL | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 cm | | | 60 cm | | | 90 cm | | | 120 cm | | |
| May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff |
| 36.2 | 28.2 | -8.0 | 35.1 | 30.9 | -4.2 | 36.4 | 36.5 | +0.1 | 37.3 | 38.7 | +1.4 |
| TOTAL SEASONAL USE (VOL %) -10.7 | | | | | | | | | | | |

| SOIL MOISTURE (VOL %) | | | | | | REED CANARY GRASS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 cm | | | 60 cm | | | 90 cm | | | 120 cm | | |
| May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff | May16 | Sep 4 | Diff |
| 37.6 | 30.6 | -7.0 | 39.0 | 38.7 | -0.3 | 37.3 | 39.1 | +1.8 | 37.6 | 38.6 | +1.0 |
| TOTAL SEASONAL USE (VOL %) -4.5 | | | | | | | | | | | |

# CHEMICAL QUALITY OF PLANTS, SOILS AND SHALLOW GROUNDWATERS OF SALINE SEEPS IN SOUTHERN ALBERTA, 1991

B. Read and D. Wentz[1]

## INTRODUCTION

A three year study resumed in 1991 to determine if toxic levels of chemicals, in particular trace elements, are present in plants, surface soils and shallow groundwaters within saline seeps in southern Alberta. The Conservation and Development Branch of Alberta Agriculture recommends seeding salt-tolerant forages in the saline seep as a control measure for soil salinity. If toxic levels of inorganic chemicals are present in shallow groundwaters and soils of saline seeps, then these toxic elements may accumulate in the forages and subsequently in livestock. This may have important nutritional implications for humans.

## METHODS

Plant, soil and groundwater samples were obtained from 15 different dryland salinity investigation sites (saline seeps) in the County of Vulcan and at 12 sites (saline seeps) in the County of Lethbridge. Samples were transported back to the laboratory the same day and prepared for analyses. Plant samples were oven-dried at 65 degrees C. for 24 hours, placed in plastic bags and stored in a deep-freeze until analyzed. Soil samples were air-dried and stored. Saturation paste extracts were later obtained, and solution extracts were stored at 4 degrees C. until analyzed. Groundwater samples were filtered through a 0.45 micrometer filter in the lab and acidified. Electrical conductivity, pH, nitrate and bicarbonate and carbonate contents were determined on water samples within 48 hours. Water samples were stored at 4 degrees C., for later analyses of trace elements.

Trace elements in plant, soil and groundwater samples were determined by inductively coupled plasma (ICP) in the Soil and Animal Nutrition Laboratory of the Plant Industry Division of Alberta Agriculture, Edmonton. Trace elements in soils and water samples were also determined by atomic absorption techniques in the laboratory of the Land Evaluation and Reclamation Branch of Alberta Agriculture in Lethbridge. The following chemical constituents were determined in plant, soil and water samples: Ca, Mg, Na, K, SO4, Cl, Al, Cd, Cr, Cu, Hg, Fe, Mn, Mo, Zn, Pb, Co, As, Se, P, S, B and I.

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## RESULTS

The following elements or compounds found in the shallow groundwaters of the 27 saline seeps exceeded maximum recommended limits for livestock water quality (Environment Canada 1987). These elements or compounds, in decreasing order of abundance, were fluorine = nitrates > selenium > mercury > cadmium > lead > arsenic (Table 1a).

The following elements or compounds found in the shallow groundwaters of the 27 saline seeps exceeded maximum recommended limits for irrigation water quality (Environment Canada 1987). These elements, in decreasing order of abundance, were fluorine > selenium > arsenic > molybdenum > lead > chloride (Table 1b).

The following elements found in the plants within the 27 saline seeps exceeded maximum recommended limits for livestock feed and water quality (Alberta Agriculture 1987; Environment Canada 1987). These elements, in decreasing order of abundance, were aluminum = boron = copper (sheep, cattle) = lead = mercury = molybdenum = sulfur > cadmium > selenium > cobalt > copper (swine, poultry) > arsenic (Table 2).

The following elements or compounds found in the soil (as soil solution extract) within the 27 saline seeps exceeded the maximum recommended limits for livestock water quality (Environment Canada 1987). These elements or compounds, in decreasing order of abundance, were cadimum = fluorine = mercury = nitrate = selenium > boron > sulfates (Table 3a).

The following elements found in the soil (as soil solution extract) within the 27 saline seeps exceeded the maximum recommended limits for irrigation water quality (Environment Canada 1987). These elements, in decreasing order of abundance, were arsenic = fluorine = molybdenum = selenium > boron > manganese (Table 3b).

## CONCLUSIONS

Over the two years which this study has been conducted, a total of 57 sites in southern Alberta have been investigated, from which the chemical quality of plants, soils and groundwaters in saline seeps has been determined. In 1992, the project will expand to investigate the County of Cypress and the MD's of Willow Creek, Cardston, Taber and Pincher Creek. It is hoped that eventually all regions of the province where salinity is found will be included in this study.

## ACKNOWLEDGEMENTS

The authors wish to thank Dan Heany and staff of the Soils and Animal Nutrition Laboratory (Soils Branch), Edmonton; and Lab Services (Land Evaluation and Reclamation Branch), Lethbridge for their analytical assistance.

Table 1. Chemical Quality of Groundwater

| | SAMPLE | CHEMICAL | % OF SITES > MAX. LIMIT | MAX. LIMIT ppm | TYPE OF GUIDELINES |
|---|---|---|---|---|---|
| (a) | water | fluorine | 100 | 2.0 | livestock |
| | water | nitrates | 100 | 100 | livestock |
| | water | selenium | 78 | 0.05 | livestock |
| | water | mercury | 48 | 0.003 | livestock |
| | water | cadmium | 22 | 0.02 | livestock |
| | water | lead | 4 | 0.1 | livestock |
| | water | arsenic | 3 | 5.0 | livestock |
| (b) | water | fluorine | 100 | 1.0 | irrigation |
| | water | selenium | 78 | 0.05 | irrigation |
| | water | arsenic | 33 | 0.1 | irrigation |
| | water | molybdenum | 30 | 0.05 | irrigation |
| | water | lead | 4 | 0.2 | irrigation |
| | water | chloride | 3 | 700 | irrigation |

Table 2. Chemical Quality of Plants

| | | | | |
|---|---|---|---|---|
| plant | aluminum | 100 | 5.0 | livestock |
| plant | boron | 100 | 5.0 | livestock |
| plant | copper | 100 | 0.5a-1.0b | livestock |
| plant | lead | 100 | 0.1 | livestock |
| plant | mercury | 100 | 0.003 | livestock |
| plant | molybdenum | 100 | 0.5 | livestock |
| plant | sulfur | 100 | 1000 | livestock |
| plant | cadmium | 96 | 0.02 | livestock |
| plant | selenium | 89 | 0.05 | livestock |
| plant | cobalt | 59 | 1.0 | livestock |
| plant | copper | 56 | 5.0c | livestock |
| plant | arsenic | 26 | 5.0 | livestock |

a= sheep b= cattle c= swine and poultry

Table 3. Chemical Quality of Soil (soln)

| | | | | | |
|---|---|---|---|---|---|
| (a) | soil | cadmium | 100 | 0.02 | livestock |
| | soil | fluorine | 100 | 2.0 | livestock |
| | soil | mercury | 100 | 0.003 | livestock |
| | soil | nitrates | 100 | 100 | livestock |
| | soil | selenium | 100 | 0.05 | livestock |
| | soil | boron | 70 | 5.0 | livestock |
| | soil | sulfates | 15 | 1000 | livestock |
| (b) | soil | arsenic | 100 | 0.1 | irrigation |
| | soil | fluorine | 100 | 1.0 | irrigation |
| | soil | molybdenum | 100 | 0.05 | irrigation |
| | soil | selenium | 100 | 0.05 | irrigation |
| | soil | boron | 30 | 6.0 | irrigation |
| | soil | manganese | 26 | 0.2 | irrigation |

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# ROOTING DEPTH AND SOIL WATER USE OF TEN VARIETIES OF ALFALFA IN SOUTHERN ALBERTA

B. Read, V. Sawchuk and D. Wentz[1]

## INTRODUCTION

The planting of deep-rooted perennial forages is recommended on all dominant recharge areas as a control measure for dryland salinity (Alberta Agriculture). Alfalfa in particular is most suitable because of its ability to extract moisture from a greater depth and over a longer growing season than most other crops. The decision as to which variety to plant is often based on research results from Montana (Brown and Cleary 1978). Studies on Alberta soils (Wentz 1989, Beke and Graham 1989) have investigated yields of various alfalfa cultivars but information on rooting depth and soil moisture use is lacking. A two year study was initiated in 1990 (Miller and Read) to determine which alfalfa cultivar is most suitable for the vegetative control of dryland salinity based on yield, rooting depth and moisture use criteria.

## METHODS

The study site is located at the D. & G. Welsh farm (NE 23-2-15-W4) near Milk River. An alfalfa variety and fertilizer trial (Project 87-F003-1) conducted by D.Wentz has been in progress at this site since 1987. This study on rooting depth and soil water use utilizes these previously established alfalfa plots. Ten alfalfa cultivars were examined in this study (Table 1).

**Table 1. Ten alfalfa cultivars used in this study**

| Variety | Type | Root Type | Hardiness |
|---|---|---|---|
| Rambler | Dryland | Creeping | Excellent |
| Spredor II | Dryland | Strongly Creeping | Excellent |
| Pioneer 524 | Standard | Tap | Good |
| Drylander | Dryland | Strongly Creeping | Excellent |
| Algonquin | Standard | Modified Tap | Medium |
| Trumpetor | Flemish | Modified Tap | Fair |
| Beaver | Standard | Deeply Rooted Modified Tap | Medium |
| Rangelander | Dryland | Strongly Creeping | Excellent |
| Pacer | Flemish | Modified Tap | Fair |
| Heinrichs | Dryland | Moderately Creeping | Excellent |

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Investigations on rooting depth and water use were initiated in the spring of 1990 and concluded in the fall of 1991. Ten alfalfa varieties replicated three times were chosen for this study. A total of thirty alfalfa plots and three adjacent fallow plots were instrumented in the spring of 1990. One access tube was installed in each plot to a depth of approximately 6.1 metres (20 feet). Soil moisture was monitored every two weeks from spring to fall in 1990 and again in 1991. A piezometer nest and observation wells were also installed at the site to ascertain if vertical groundwater flow was upward (discharge) or downward (recharge).

Soil samples to a depth of 6.1 metres were taken from each plot during drilling operations in the growing season of 1990. Roots in soil and drift samples were then separated by sieving to determine the presence of roots at a specified depth interval. In the fall of 1991, soil cores were again collected but only visual observations were made to determine apparent rooting depth. Yield samples were obtained from each plot and yields were calculated.

Rooting depth and soil water use for each alfalfa variety was determined from a graph of soil moisture versus depth for each alfalfa cultivar and fallow plot (Figure 1). Rooting depth was determined on the graph by the intersection of the alfalfa and fallow curves. Soil water use was calculated as the area between the two curves, from a depth of 25 cm to the depth of rooting. The results in this study are reported as mean yield, rooting depth and soil water use for the three reps, from two seasons. Mean values of soil moisture for the three fallow plots were used for all results.

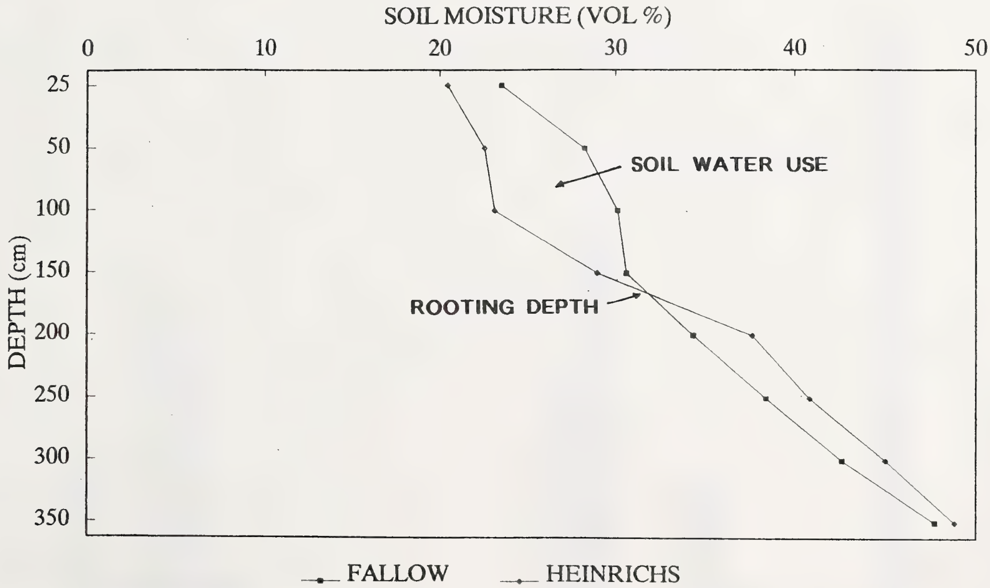


Figure 1. Example of the graph used to determine rooting depth and soil water use of each alfalfa variety.

## RESULTS

To determine which alfalfa variety was the best suited for the vegetative control of dryland salinity, each cultivar was evaluated on the basis of yield, rooting depth and soil water use (Table 2). In all three catagories, Beaver ranked first with the highest yield (3003.5 kg/ha), the deepest rooting depth (2.13 m) and the highest soil water use (11.33 cm). The performance of each variety has been ranked from one to ten (one being best) according to each of the three variables. In addition, each variety was rated for overall performance by assigning a value to each individual ranking and then totalling these values. Beaver alfalfa ranked first overall with Heinrichs and Pacer placing second and third. Pioneer ranked last.

Table 2. Yield, rooting depth and soil and water use (Average of 1990 and 1991)

| Variety | Overall Ranking | Yield Kg/ha | Ranking | Rooting Depth(m) | Ranking | Soil Water Use (cm) | Ranking |
|---|---|---|---|---|---|---|---|
| Beaver | 1 | 3003.5 | 1 | 2.13 | 1 | 11.33 | 1 |
| Heinrichs | 2 | 2396.0 | 7 | 1.65 | 3 | 9.28 | 3 |
| Pacer | 3 | 2343.0 | 9 | 2.01 | 2 | 9.65 | 2 |
| Algonquin | 4 | 2611.0 | 6 | 1.59 | 5 | 8.50 | 4 |
| Drylander | 5 | 2680.5 | 4 | 1.57 | 6 | 6.68 | 7 |
| Spredor | 6 | 2627.0 | 5 | 1.52 | 8 | 7.65 | 6 |
| Rambler | 7 | 2924.5 | 2 | 1.47 | 9 | 6.45 | 9 |
| Rangelander | 8 | 2354.0 | 8 | 1.62 | 4 | 6.63 | 8 |
| Trumpetor | 9 | 2235.0 | 10 | 1.53 | 7 | 8.33 | 5 |
| Pioneer | 10 | 2755.0 | 3 | 1.18 | 10 | 2.86 | 10 |

A number of environmental factors were present at the study site which influenced the growth of the alfalfa. As a result, caution should be exercized when interpreting the data, even though results were consistent from year one through year two of this study. Groundwater levels under the plots fluctuated from a recharge flow situation in the spring of 1990 to one of discharge in the fall of that same year. The water table later stabilized and was consistent through 1991 (Figure 2). Soil texture was consistent throughout the plot area (predominantly clay loam) but the electrical conductivity of the soil was variable. Replicate number one was non-saline while reps three and five were saline. Periods of severe drought stress compounded by winter kill affected the population of the stand. Recorded rainfall during 1990 totalled only 80 mm; 142 mm in the following year (Figure 3).

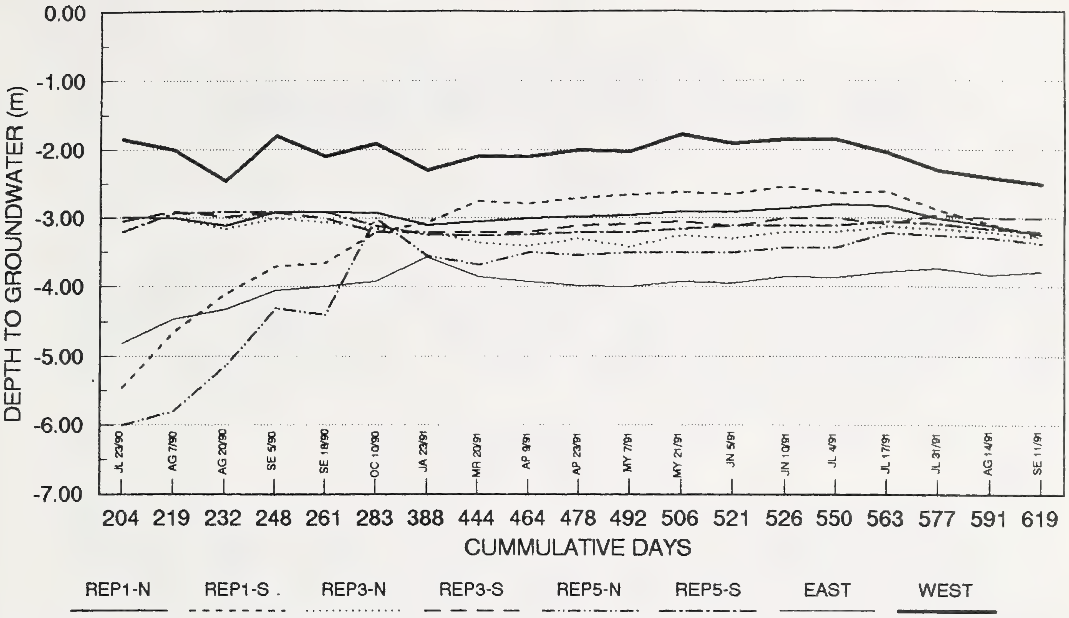


Figure 2. Groundwater movement during 1990 and 1991 growing season.

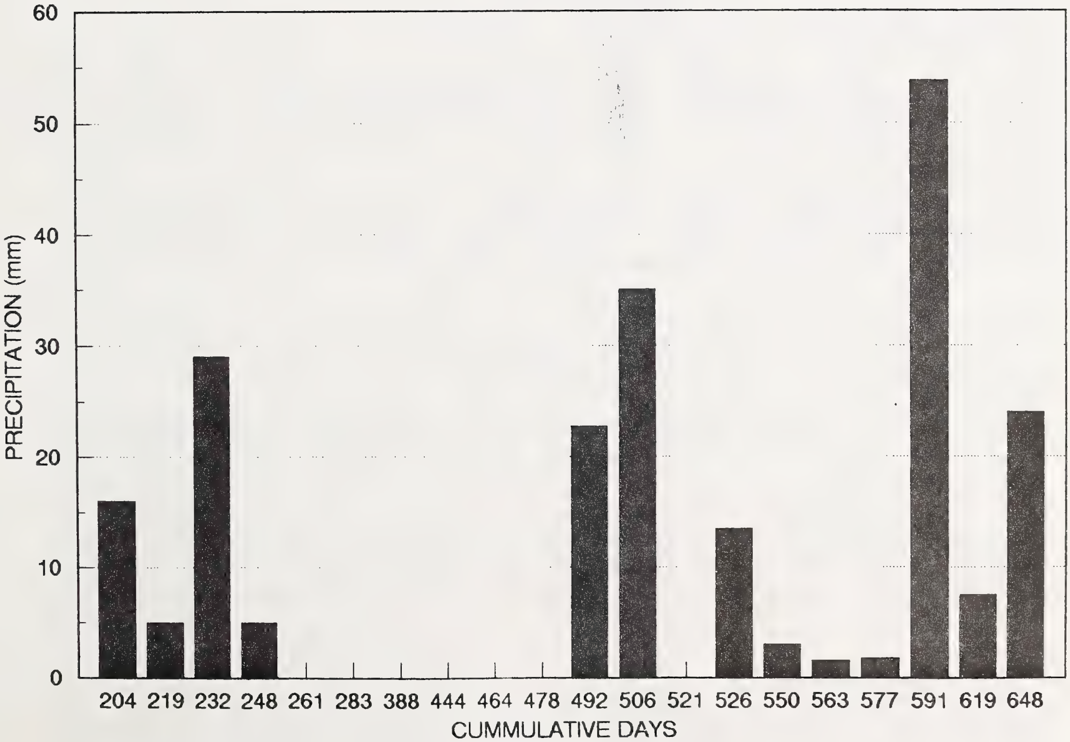


Figure 3. Rainfall 1990-1991

## SUMMARY AND CONCLUSIONS

After two seasons of study (1990, 1991). it was determined that Beaver alfalfa is the cultivar with the best overall combination of yield, rooting depth and soil water use. As such, Beaver would be strongly recommended as the cultivar of choice as a vegetative control for dryland salinity. Other varieties performed well to varying degrees in each of the respective categories, but none as consistently well as Beaver. Rambler, for example, yielded similar to Beaver, however, it ranked 9th in rooting depth and soil moisture use. If yield was the only consideration in selecting a variety, Rambler and some others would be good alternatives. If vegetative control of dryland salinity is the concern, then rooting depth and soil moisture must be considered.

## ACKNOWLEDGEMENTS

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# COMPARISON OF PERENNIAL VERSUS FLEX CROPPING OF RECHARGE AREAS TO RECLAIM SALINE SEEPS IN SOUTHERN ALBERTA

D. Wentz[1]

## ABSTRACT

A study in the County of Warner compared the effectiveness of alfalfa (Medicago sativa) and flexible cropping with annual cereals to reclaim a saline seep. The discharge area associated with the flex-cropped recharge area remained unproductive whereas the discharge area associated with the perennial-cropped recharge area improved enough over a six-year period that a barley (Hordeum vulgare) crop was subsequently seeded. This was because the water table had dropped and the surface soil chemistry in the discharge area of the latter cropping system had improved. The deep-rooted and high-moisture use alfalfa depleted stored soil water to a greater depth than shallow-rooted annual cereal crops. When water table levels in the recharge area were lowered, the lateral movement of groundwater was reduced and the saline seepage process diminished. An economic analysis of the project was conducted in conjunction with the perennial cropping study. Perennial cropping with alfalfa and alfalfa grass mix proved comparable in net return to annual flex cropping.

## INTRODUCTION

The salinization of soil in the semi-arid areas of the Great Plains of North America is a naturally occurring process. However, dryland salinity was not a major problem prior to the introduction of modern agricultural technology. Native grasses, forbs and shrubs, with their varying rooting depths, prevented the buildup of water tables. Natural salinity in Alberta has been estimated at 340,000 ha (840,000 ac) (Sommerfeldt et al 1984). The introduction of the summerfallow cropping system dramatically altered the natural eco-system. The result has been greater storage of soil moisture along with deep percolation of moisture below the root zone into the groundwater (Chang et al 1990). As a result, dryland salinity is now a major problem with an additional 670,000 ha (1,655,000 ac) of farmland affected in Alberta (Sommerfeldt et al 1984). These areas of saline seepage, often referred to as secondary dryland salinity, can be differentiated from natural saline soil conditions by their recent and local origin, saturated root-zone profile, shallow water table and sensitivity to precipitation and cropping systems (Brown et al 1982).

A saline seep is the result of saline water discharging at or near the ground surface. The cause of the discharge is the deep percolation of water in the immediate and upslope portion of a field, often referred to as the recharge area (Vander Pluym 1985). High water tables in

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discharge areas can be potentially reduced by a selective cropping system in the recharge area. Growing alfalfa in the recharge area can be the quickest and most effective way to decrease groundwater discharge in the seep area (Brown et al 1982). Lowering the water table in the saline seep or discharge area then allows recropping of the seep area with normal grain or forage crops (Halvorson 1988).

Alfalfa will produce high yields when grown on good soils with deep profiles and high water tables. The study included a comparison of net returns from several annual cropping rotations and alfalfa forage production. The objective of this study was to compare the agronomic and economic benefits of growing alfalfa or an alfalfa-grass mix versus annual cereal crops in recharge areas to reclaim saline seeps under southern Alberta conditions.

## MATERIALS AND METHODS

The study site selected was located in an area with a high incidence of saline seepage, on the north-facing slope of the Milk River Ridge. Agriculture Canada, Prairie Farm Rehabilitation Administration (PFRA) investigated this site in 1982 as part of the Dryland Salinity Investigation Program.

The soils in the southern portion of the study site are derived from medium-textured, moderately-calcareous glacial till. PFRA identified this hummocky ridge as the dominant recharge area. The soils in the northern portion or discharge area of the study site were identified as fine-textured lacustrine material with a gently undulating topography. The soils in the study area were classified as Orthic Brown Chernozem (Kjearsgaard et al 1984).

The saline seep problem was identified as a texture-change seep. The recharge area has a higher permeability level than the underlying material. Water moves downward through the root zone and laterally downslope where it encounters the fine-textured lacustrine material (Brown et al 1982).

PFRA installed 28 observation wells 3 to 10 m in depth. All wells were installed with a B-31 Mobile Drill Truck. Wells were allowed time to stabilize, then monitoring was done from 1982 to present. Well BA6 was installed to a depth of 6.8 m, BA26 to 4.0 m, BA19 to 7.7 m, BA20 to 7.5 m. Water table levels from these four of the 28 sites are reported in this study.

Well number BA6 is located in the sixty acres designated as the recharge area that was seeded to alfalfa and an alfalfa-grass mix. Well number BA26 is located in the 20 acre discharge area about 150 m to the northeast of BA6 (Figure 1). The 20 acre discharge area was fallowed. Well number BA20 is located in the recharge area that was flex-cropped with annual cereal crops. Well number BA19 is located in the discharge area about 150 m north of BA20 (Figure 1). The discharge area was seeded to annual cereals but no production occurred because of high salinity.

Soil samples were taken at BA26 in 1982 at the time of installation of the water table well, in 1985 and in the fall of 1990. Electrical conductivity (EC), pH, soluble Ca + Mg, soluble Na and sodium adsorption ratio (SAR) were determined from saturated paste extracts (Rhoades 1982).

An analysis of the economics of growing perennial forages such as alfalfa in recharge areas was initiated in 1984. The methods of analysis was to compare costs and returns for conventional cropping systems with alfalfa production. Alfalfa and an alfalfa-grass mix were used as the perennial forage crop but for purposes of this study, the differences are not considered. All yield and price data was collected for the period of the study and were averaged over the six year study.

## RESULTS

The water table in the recharge area (BA6) on October 29, 1982 was at a depth of 3.3 m (Figure 2). Alfalfa was seeded into the recharge area in the spring of 1983. The water table declined to about 5 m (bottom of well) by May 7, 1984; and has remained relatively constant for the remainder of the study. Water table levels did not increase as a result of the above average precipitation received during June 1991. The water table in the discharge area (well BA26), prior to seeding alfalfa in the recharge area, was 0.9 m on October 29, 1982. The water table declined to a depth of about 2.0 m by October 17, 1983 and then fluctuated only slightly for the remainder of the study.

The water table in the recharge area (well BA20) of the flex-cropped system had an initial water table depth of 3.6 m on October 29, 1982 (Figure 3). The water table gradually increased during the study and reached a depth of .52 m by July 2, 1991 as a result of above average precipitation during June 1991. The December 23, 1991 reading indicated the water table level had receded back to 2.4 m. The water table in the discharge area (well BA19) had an initial water table depth of 2.2 m on October 29, 1982 (Figure 3) and reached a depth of 0.35 m on July 2, 1991 as a result of above average precipitation during June 1991. The December 23, 1991 reading showed BA19 had receded to 1.6 m. This area was in cereal grain production in 1991.

Soil samples taken from the discharge area of the alfalfa cropping system (BA26) in 1982, 1985 and 1990 indicated that in the surface 30 cm of soil, EC and SAR levels have substantially improved (Table 1). The EC declined from 13.3 dS $m^{-1}$ in 1982 to 1.7 dS $m^{-1}$ in 1990. This was caused by a declining water table (Figure 2) and subsequent leaching. Over the same time period the SAR dropped from 26.5 to 4.3. The sodium ion level declined from 122.1 to 8.3 meq $L^{-1}$. The Ca + Mg level dropped from 43.5 to 7.5 meq $L^{-1}$ over the 8-year period. The sodium to calcium plus magnesium ratio in 1990 was 1 to 1, reflecting an improvement in soil quality. Sodium is undesirable because it deteriorates soil structure and restricts plant growth.

The yield and price data (gross return) were collected for all crops between 1984 and 1989. Cereal crops prices were based on provincial averages. Prices for the perennial forage crops were specific to this study area. Gross margins were calculated and averaged for the six-year study period. Gross margins reflected the difference between gross return and cash costs. Cash costs included fertilizer, seed, fuel, labor, crop insurance, operation and maintenance of equipment and miscellaneous production costs. The gross margin for alfalfa was $23.03 per acre year (Table 2). This ranked 4th out of the 7 combinations of annual flex cropping and perennial forage cropping. The most profitable rotation was continuous winter wheat with an average

gross margin of $32.26 per acre per year. Continuous cropping with winter wheat will eventually result in reduced gross margins because of weed infestations and therefore, it is not practical. Rotations with fallow were considered undesirable in problem recharge areas because of the increased saline seepage potential (Table 2).

Return to land reflects the difference between gross return and total costs minus land costs. Total costs include items like machinery depreciation, taxes and non-field expenses, often referred to as fixed costs and cash costs. Again alfalfa hay ranked 4th out of the seven combinations. The profit margin between the top four rotations which includes alfalfa hay is $3.96. The fixed costs associated with hay production were less than for cereal production. These factors make alfalfa production an economic alternative when considering agronomic controls for dryland salinity (Table 2).

## SUMMARY AND CONCLUSION

The use of a perennial cropping system such as alfalfa or alfalfa grass mix may reverse the effect of annual cropping and summerfallow rotations. The high moisture requirements of alfalfa exceed the annual rainfall levels of the study area by approximately 15 cm. The deep rooting capability of alfalfa enables it to utilize stored soil water to depths of 5 m or more. The utilization of stored soil water results in declining water table levels and diminishes the saline seepage problem. The result is an increased storage capability in the soil profile that holds excess precipitation and prevents discharge. Over time, precipitation will gradually leach soluble salts out of the root zone in discharge areas resulting in improved growing conditions. Once the water table is lowered sufficiently and soil quality improved, annual crop production can resume.

Perennial cropping systems are economically competitive with annual cropping systems when planted in recharge areas. Proper management will ensure satisfactory yields. This combined with low input costs makes alfalfa a good alternative when soil salinity is a problem.

**Table 1. Chemistry of surface soil from saline seep area site 26**

| Date | Depth (cm) | pH | EC (dS $m^{-1}$) | Ca + Mg | Na | K | SAR |
|---|---|---|---|---|---|---|---|
| | | | | ----------meq $L^{-1}$---------- | | | |
| 1982 | 0-30 | 8.2 | 13.3 | 43.5 | 122.1 | 0.2 | 26.5 |
| 1985 | 0-30 | 7.4 | 10.5 | 28.5 | 101.2 | 0.4 | 26.8 |
| 1990 | 0-30 | 8.0 | 1.7 | 7.5 | 8.3 | 1.8 | 4.3 |

Table 2. **Gross margin and return to land, producer and provincial prices, B. Atkins (Smith 1990)**

| Crop Rotation | Price Scenario Producer | Provincial* |
|---|---|---|
| | Gross Margin $/ac/yr | |
| Spring wheat - fallow | 20.00 | 29.53 |
| Spring wheat - spring wheat - fallow | 13.81 | 22.08 |
| Continuous spring wheat | 0.50 | 6.27 |
| Winter wheat - fallow | 25.08 | 30.17 |
| Continuous winter wheat | 24.36 | 32.26 |
| Spring wheat - barley - fallow | 14.42 | 14.92 |
| Alfalfa hay | 23.02 | 23.03 |
| | Return to Land $/ac/yr | |
| Spring wheat - fallow | 4.52 | 14.05 |
| Spring wheat - spring wheat - fallow | -1.36 | 6.92 |
| Continuous spring wheat | -16.54 | -10.78 |
| Winter wheat - fallow | 9.58 | 14.66 |
| Continuous winter wheat | 5.39 | 13.30 |
| Spring wheat - barley - fallow | -1.48 | -0.97 |
| Alfalfa hay | 10.70 | 10.70 |

* Provincial prices for the wheats, and for feed barley.

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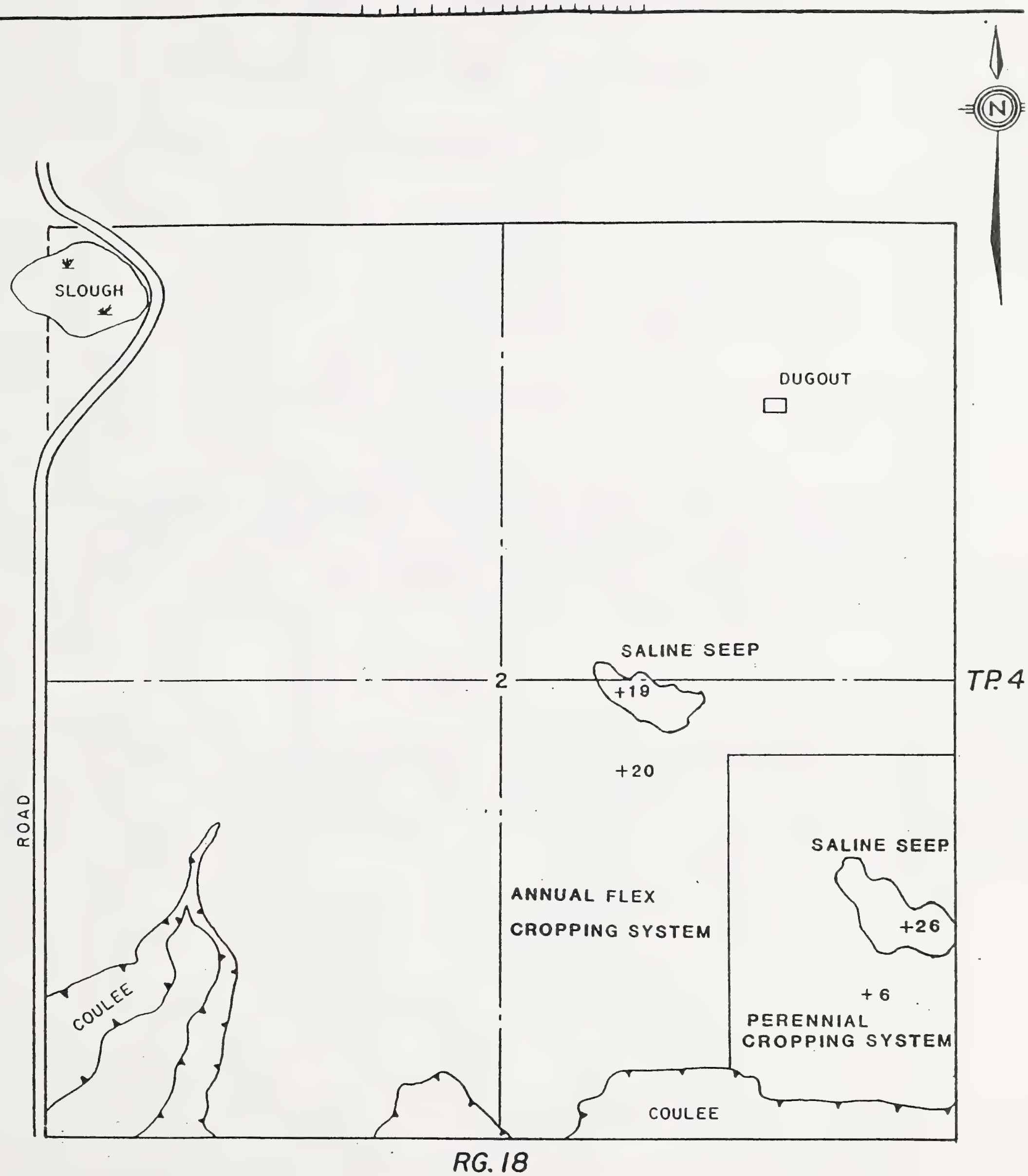


**FIGURE 1**

**LOCATION OF RESEARCH SITE**

**AND WATER TABLE WELL MONITORING SITES**

MICROFILM DATE
DRAWING No.
FILE No.

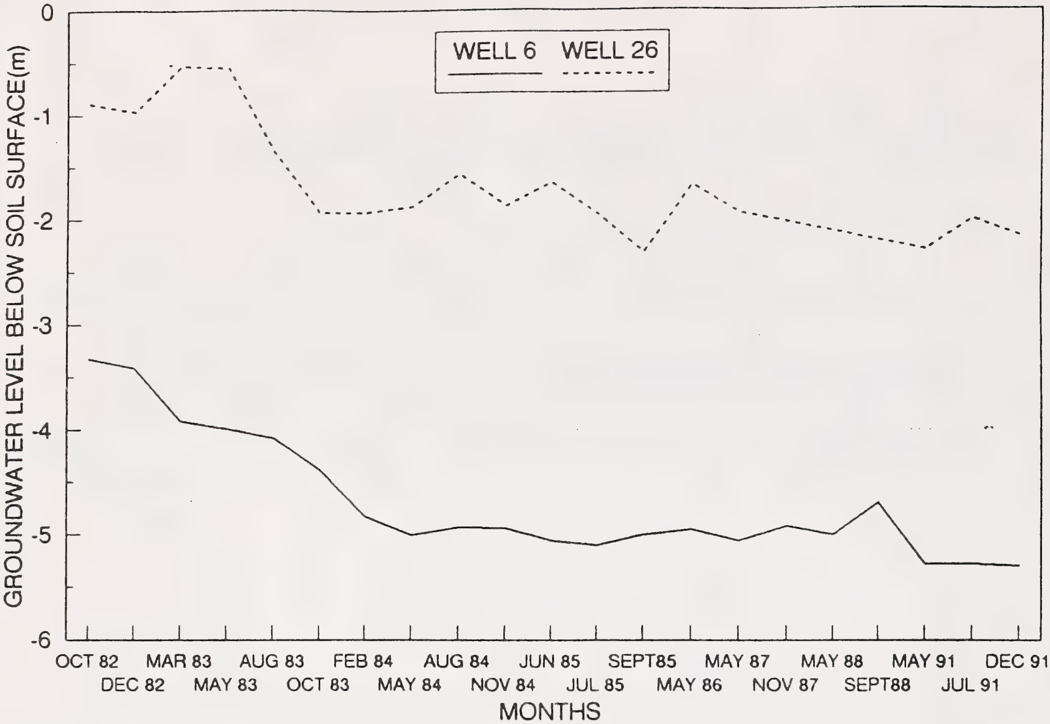


Figure 2. Summary of WTW Levels For # 6 and 26

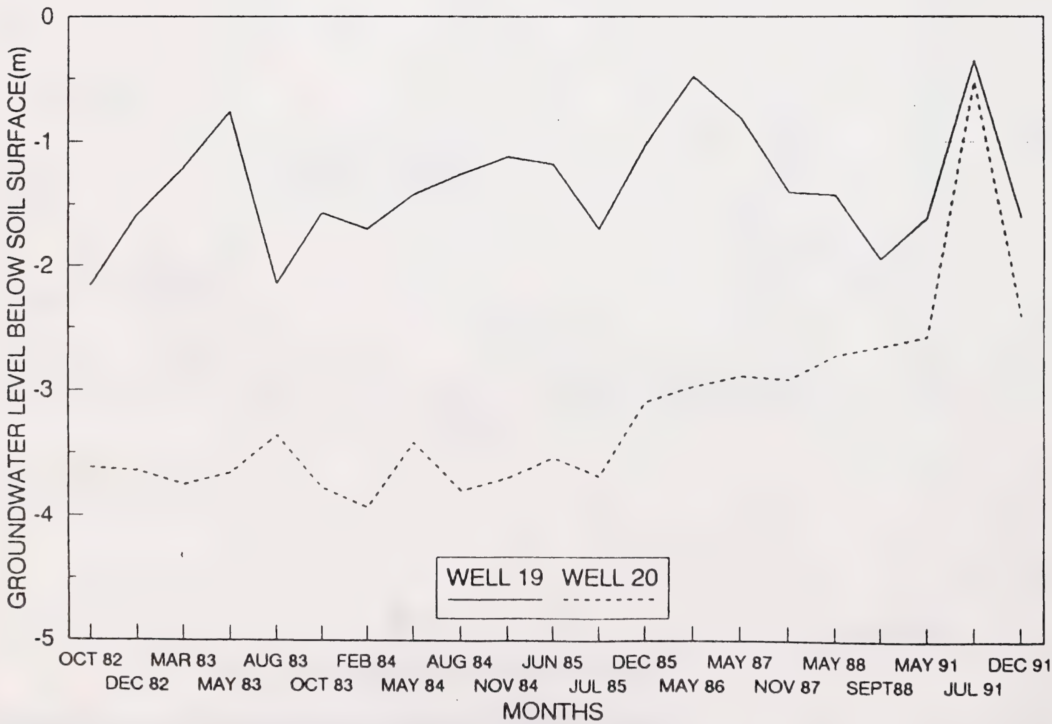


Figure 3. Summary of WTW Levels For # 19 and 20

# ECONOMIC IMPLICATIONS OF ALFALFA PRODUCTION TO CONTROL DRYLAND SALINE SEEPS

E.G. Smith[1], J.C. Payne[2] and D.J. Wentz[3]

## INTRODUCTION

There are a number of technically feasible means of controlling dryland saline seeps. Subsurface drainage is one method that can be used to lower water tables or intercept groundwater, but results can be difficult to achieve in dryland saline seeps. Economic considerations combined with geographic and environmental factors prevent the widespread use of drainage into watercourses for solving dryland salinity problems (Oosterveld, 1978).

Vegetative controls include the use of flexible cropping or seeding of perennial forages such as alfalfa in the recharge area. Alfalfa can often provide the quickest and most effective way to decrease groundwater flow to the discharge area (Brown et. al. 1982).

A study was carried out in southern Alberta with the goal of determining the economic feasibility and physical performance of flexible cropping and alfalfa to control dryland salinity. This paper examines the results of four producers from the Warner - Milk River area of Alberta, who were part of a seven year study that included 50 producers.

## METHOD

Dryland salinity investigations were completed for the farmers involved in this economic study. Wells were installed to measure water table depths over time in recharge and discharge areas, electrical conductivity (EC) measurements were taken of soil from the saline seep area, and recommendations were provided. These four producers planted alfalfa in recharge areas, as well as continuous cropped with annual cereal crops on other recharge areas. The final decision on the controls selected and the area controls were applied to, was left to the producer.

The Field Services Branch of Alberta Agriculture, in cooperation with the Production Economics Branch and cooperating farmers, collected farm cost and return data on a field basis beginning in 1984. Information collected on a field basis included yields, farm prices, input costs (fertilizer, pesticides, etc.), insurance, machine use and land costs (taxes and interest). A complete farm equipment inventory was used to determine operating costs and depreciation. Machinery costs were then allocated to fields based on the proportion of use in a field. Labour hours were determined by machine use in a field. A LOTUS spread-

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sheet program was developed and used to calculate the costs and returns.

From the farm data collected, costs and returns of individual fields, as well as for the entire farm, were determined. Individual farm and all farm summaries were returned to producers to give an indication of their farm's economic performance and the average performance of the group. The field analysis allowed costs and returns to be determined for individual crops including alfalfa establishment and production, fallow versus stubble crops and for owned versus rented land.

## ECONOMIC RESULTS

Alfalfa was established in 1984 or 1985, depending on the farm. All crops had variable yields over the 1984 to 1990 study period. Economic losses from alfalfa tended to be lower than annual cereal crops during periods of drought because alfalfa prices increased and production costs (primarily harvesting) decreased. Two producers either sold their hay standing in the field or had it custom harvested, and did not require haying equipment. In contrast, losses in cereal production were large because grain prices are not affected by local drought conditions and input costs (fertilizer, seed, pesticide, machinery) remained relatively high.

Average variable and fixed costs as well as gross margin and return to land for summerfallow (F), hard red spring (HRS) wheat, durum (D) wheat, winter wheat (WW) on fallow (F) and stubble (S), alfalfa establishment (Est. Alf.) and alfalfa (Alf. Hay) are reported in Table 1. For these comparisons, final grain prices were used which include Canadian Wheat Board payments. Costs and returns are an average for the four farmers and the seven study years. The three annual cereal crops analyzed were not produced every year on each farm, therefore, the averages need to be used with this in mind because differences in costs and returns could be due to the years in which they were produced. There were also differences in costs and returns for individual farms over the seven years of the study. These ranges are presented in Table 1.

The variable costs in this study include seed, fertilizer, pesticides, equipment operations and maintenance, insurance, labour and miscellaneous expenses. Fixed costs include land costs (taxes, rent and interest), interest on equipment, machinery depreciation and out of field costs (utilities, building repair and insurance, and miscellaneous). Gross margin is revenue (price X yield) less variable costs. Gross margin, as used here, is equivalent to the standard accounting practice term, contribution margin. The return to land is gross margin less all fixed costs, except land costs.

From Table 1, the average variable costs of summerfallow were $8.72 per acre, and fixed costs were $22.86. Average grain production (fallow or stubble) costs ranged from $43.71 to $54.81 per acre. Alfalfa establishment costs were $38.93 per acre and alfalfa hay production costs were $16.43 per acre. Over the seven years of the study, the trend of variable costs was downward. This decline in costs was likely the result of lower grain prices and subsequent adjustments to production.

**TABLE 1. Average and range of cost and return data by crop for four producers in the Warner-Milk River area.**

| | COSTS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | VARIABLE | | FIXED* | | GROSS MARGIN** | | RETURN TO LAND | |
| | AVERAGE | RANGE | AVERAGE | RANGE | AVERAGE | RANGE | AVERAGE | RANGE |
| | ($/acre) | | | | | | | |
| F | 8.72 | (3.34 to 15.68) | 22.86 | (6.65 to 56.25) | -8.72 | (-15.68 to -3.34) | -20.25 | (-27.80 to -9.89) |
| HRS on F | 51.98 | (32.26 to 102.76) | 28.73 | (13.16 to 55.33) | 45.75 | (-12.48 to 89.89) | 23.04 | (-25.41 to 72.41) |
| D on F | 44.67 | (27.69 to 69.56) | 41.16 | (24.09 to 63.38) | 70.56 | (-6.32 to 184.31) | 49.41 | (-32.14 to 165.60) |
| WW on F | 46.36 | (26.14 to 84.07) | 36.71 | (24.09 to 60.97) | 63.59 | (5.68 to 126.70) | 38.08 | (-31.78 to 108.09) |
| HRS on S | 54.81 | (34.41 to 81.53) | 41.21 | (25.05 to 74.79) | 4.56 | (-60.00 to 71.42) | -21.90 | (-110.47 to 52.84) |
| D on S | 48.59 | (23.13 to 70.68) | 32.13 | (20.07 to 48.88) | 32.86 | (-43.88 to 84.67) | 10.32 | (-74.82 to 61.97) |
| WW on S | 43.71 | (27.87 to 63.54) | 31.60 | (7.86 to 76.01) | 40.52 | (-34.82 to 104.54) | 19.20 | (-63.26 to 81.84) |
| Est. Alf. | 38.93 | (14.94 to 55.69) | 26.48 | (6.71 to 43.22) | -32.68 | (-55.69 to 7.08) | -59.16 | (-96.54 to -21.65) |
| Alf. Hay | 16.43 | (0 to 62.60) | 30.31 | (5.21 to 60.93) | 51.39 | (-3.48 to 161.59) | 37.43 | (-37.45 to 122.99) |

* Fixed costs will include land payments, which not all producers had.
** Gross Margin is returns less variable costs and is synonymous with Contribution Margin.

Abbreviations:
F = Fallow
S = Stubble
WW = Winter Wheat
HRS = Hard Red Spring Wheat
D = Durum Wheat
Alf = Alfalfa

The average return to land was -$20.25 per acre for summerfallow, $23.04 to $49.41 per acre for cereal on fallow, and -$21.90 to $19.20 per acre for cereal on stubble, -$59.16 per acre for alfalfa establishment and $37.43 per acre for alfalfa production. The return to land showed more variation than variable costs, primarily because of yield variability.

To compare the returns of various crop rotations against alfalfa, Table 2 was developed. Comparisons were made only for crops on a farm that were grown during the same time period as alfalfa. This comparison will remove possible year and producer effects present in simple averages. For farm 1, continuous barley production was the only comparison that could be made with alfalfa because barley on stubble was the only crop consistently grown every year. For farm 4, comparisons with alfalfa could be made with HRS, durum and winter wheat in a rotation with fallow or continuously cropped.

The return to land from continuous barley production on farm 1 was $84.14 per acre less than alfalfa production (Table 2). On farm 2, barley was only $2.58 per acre less than alfalfa. Farm differences occurred because of yield and cost differences (in some cases machine costs were very different). On farm 2, returns from continuous durum wheat were $19.58 higher than alfalfa. On farms 3 and 4, cereal grain rotations generally had lower returns than alfalfa, reflected by negative values in Table 2. Of the wheat rotations listed in Table 2, winter wheat had higher returns than spring wheat.

The number of years it would take to pay back the establishment cost of alfalfa was determined for each producer. The results were extremely variable and largely depended on the timing of establishment. Farm 1 more than covered off establishment costs with the first hay crop because ideal weather produced high yields. In general, establishment costs were covered off by the second hay crop. By the fifth hay crop, the returns from alfalfa, including establishment costs, were comparable to cereal crop production.

## WATER TABLE WELL RESULTS

The effectiveness of alfalfa in lowering water tables was determined for each of the four farms. The number of wells installed on each farm varied. Wells were monitored periodically from 1982 to 1991.

Over 320 acres of alfalfa were planted on farm 1. Changes in water table levels are reflected in Fig. 1. Water table well #44 is located in a recharge area which was continuously cropped to barley. Water table levels decreased from 2.2 meters in 1985 to 2.8 meters in 1991. Water table well #2 is located in a recharge area which was seeded to alfalfa. Well #2 was at 1.9 meters in 1985 but was destroyed in May 1989. The last reading was 4.0 meters.

Water table wells located in discharge sites on farm 2 also showed declines (Fig. 2). Approximately 80 acres of alfalfa were planted. Water table well #13 decreased from 1.0 meter in November 1982 to 3.0 meters by December 1991. Water table well #3 decreased from 1.2 meters in November 1982 to 1.8 meters in December 1991. It should be noted that the area around well #3 was not seeded to alfalfa but was continuously cropped. This could explain the smaller decrease in water table depth at well #3.

**Table 2. Returns by crop rotation, relative to alfalfa, for four producers in the Warner-Milk River area**

| Farm | Crop Rotation | Gross Margin* | Return to Land |
|---|---|---|---|
| | | ----------($/acre)-------- | |
| Farm 1 | Continuous Barley | -37.52 | -84.14 |
| Farm 2 | Continuous Barley | 8.39 | - 2.58 |
| | Continuous Durum Wheat | 30.56 | 19.58 |
| Farm 3 | HRS Wheat - Fallow | - 0.74 | - 3.13 |
| | Winter Wheat - Fallow | 4.79 | 1.60 |
| | Continuous HRS Wheat | -19.33 | -24.95 |
| | Continuous Winter Wheat | 6.95 | - 0.60 |
| Farm 4 | HRS Wheat - Fallow | - 9.23 | -22.37 |
| | Durum Wheat - Fallow | - 7.69 | -21.44 |
| | Winter Wheat - Fallow | 1.88 | -12.50 |
| | Continuous HRS Wheat | - 8.17 | -26.38 |
| | Continuous Durum Wheat | - 8.80 | -27.31 |
| | Continuous Winter Wheat | 9.65 | - 7.75 |

* Gross Margin is returns less variable costs and is synonymous with Contribution Margin.

Approximately 60 acres of alfalfa were planted in the recharge area on farm 3. Changes in these water table levels are shown in Fig. 3.Water table well #6 is located in the recharge area planted to alfalfa. Well #6 decreased from 3.3 meters in October 1982 to 5 meters by May 1984. Well #20 is located in the recharge area that was flex cropped with annual cereals. Well #20 had an initial water table depth of 3.6 meters in 1982. The water table gradually increased over time and reached a depth of 0.5 meters by July, 1991 following a period of above average precipitation. The water table then fell to a level of 2.2 meters by December, 1991.

Farm 4 had 30 acres of alfalfa seeded on the recharge area of the saline seep. Water table wells #13 and #16 are located in this area. Water table well #13 declined from 3.1 meters in 1982 and was dry to bottom of pipe in December 1991 (Fig. 4). Water table well #16 declined from 2.0 meters in 1982 and was dry to bottom of pipe by December, 1991. Water table well # 1 is located in an area which was cropped to annual cereals. Well #11 showed gradual decline from 1.9 meters in 1982 to 3.3 meters in 1988. The water table then rebounded to 2.4 meters in 1989.

Data collected during the study period indicates that alfalfa has had greater impact on lowering water tables than annual cereal crops. A lowering or elimination of the water table in the saline seep will allow the process of reclamation to occur (Brown and Miller, 1978).

## CONCLUSIONS AND FUTURE DIRECTION

Economic returns from alfalfa production on recharge areas were higher than from spring wheat production during the 1984 to 1990 period. Only durum and winter wheat on fallow produced returns higher than alfalfa. Water table wells located in recharge areas planted to alfalfa, showed greater declines than those located in areas which were flex cropped. It can be concluded that alfalfa is economically feasible and physically capable of controlling dryland salinity. In contrast, flexible cropping generally gave negative economic returns and had limited effects on lowering water tables for the farms in this study. It is concluded that flexible cropping with annual cereals is a less desirable method of controlling dryland salinity.

Alfalfa crops should be maintained for at least 5 years to recover establishment costs and provide returns comparable to cereal production. Data indicates that alfalfa continued to lower water tables five to six years after establishment.

Future studies should be directed towards economic analysis of government support programs on alfalfa production for soil conservation purposes. Programs initiated in the past have tended to support summerfallow and annual crop production to the detriment of forage crop production and soil conservation practices.

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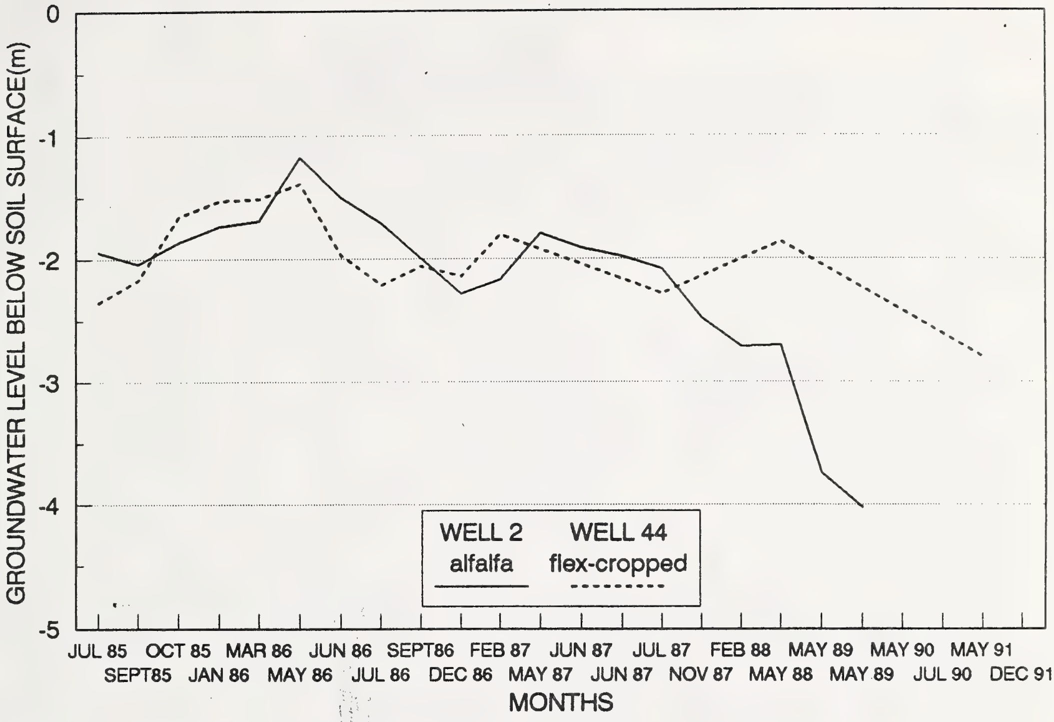


Figure 1. Summary of WTW levels for # 2 and 44 - farm 1

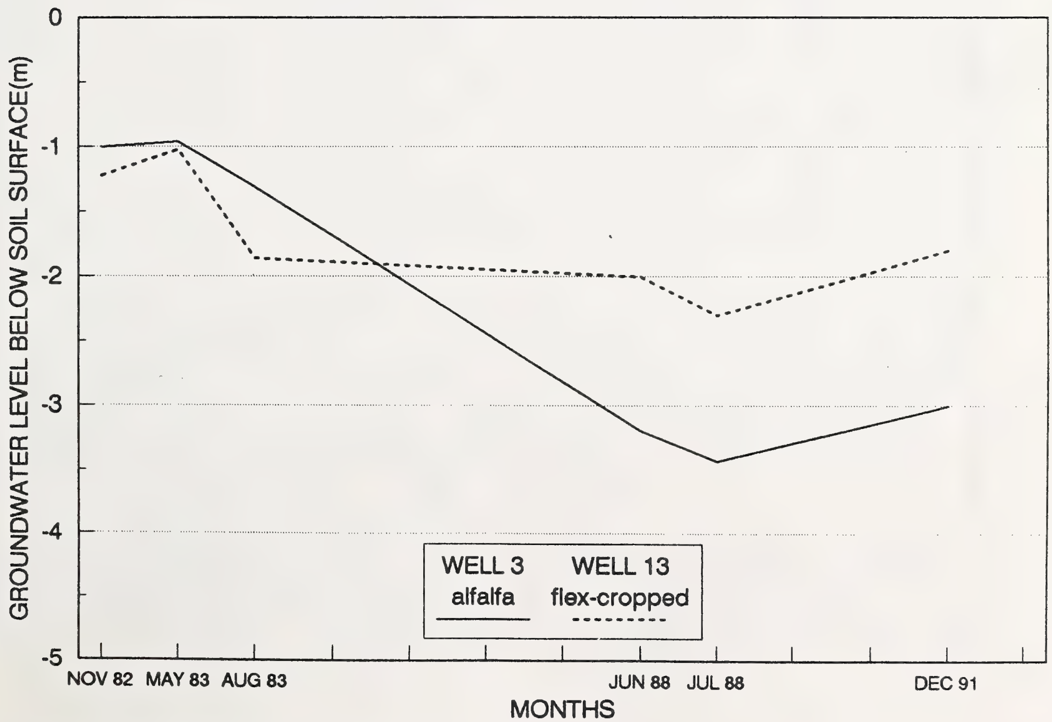


Figure 2. Summary of WTW levels for # 3 and 13 - farm 2

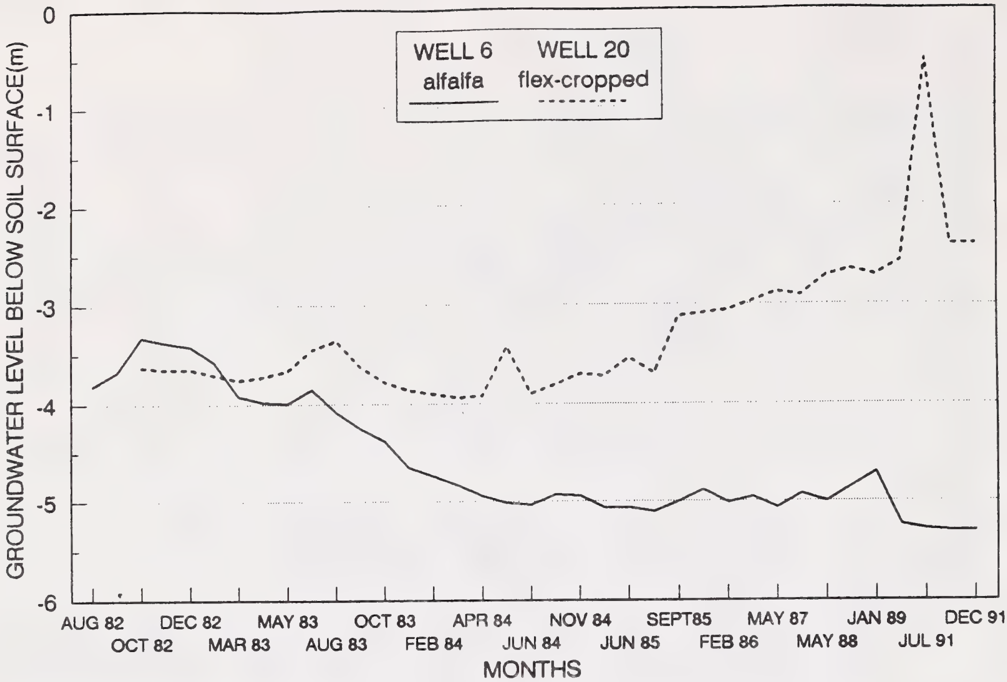


Figure 3. Summary of WTW levels for # 6 and 20 - farm 3

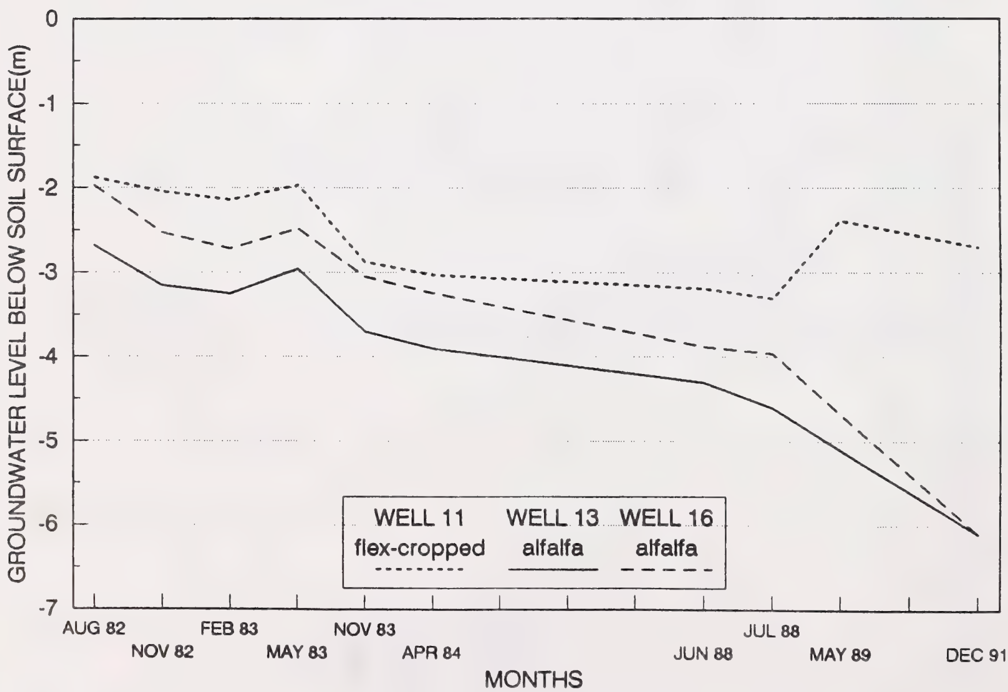


Figure 4. Summary of WTW levels for # 11, 13 and 16 - farm 4

# EVALUATION OF THE DAMMER DIKER FOR INCREASING SOIL MOISTURE AND YIELDS IN SOUTHERN ALBERTA

A. E. Howard and J. Michielsen[1]

## INTRODUCTION

The Dammer-Diker (TM) is an implement designed to improve soil moisture storage by ripping the soil to improve infiltration and pocketing the surface to retain more water. Longley (1984) reported that the Dammer-Diker increased soil moisture storage, reduced runoff, and increased yields of row crops and small grains under irrigated conditions in Oregon. Although it has been used primarily on irrigated land, much interest has been directed toward the potential of the Dammer-Diker to improve crop production in dryland areas subject to moisture shortages and slowly-permeable soils. If overwinter precipitation can be utilized to improve spring soil moisture levels, the need for summerfallow is reduced and any increase in yield and corresponding increase in residue provides the opportunity for better soil cover. Demonstrations with the Dammer-Diker have shown that dryland crops with higher yields and more vegetative growth were produced on the treated portions of the field. Questions have arisen as to how consistent these benefits are, and whether they are due to the ripping action alone, or the combined effect of ripping and surface water detention, or other causes.

Use of ripping to improve infiltration of growing season precipitation may have limited success in the Brown soil zone, since shortages of growing season rainfall are the most limiting factor for dryland crop production (Chang et al 1986; Lickacz, 1990). Ripping studies have shown however, that when combined with snow trapping, significant increases in infiltration of snowmelt can occur, resulting in a higher spring soil moisture reserve (McConkey et al, 1988; Gray et al, 1990). Since pocketing the soil in the ripping tracks has the potential to increase water storage over conventional ripping, a need existed to examine the Dammer-Diker combined with snow trapping to determine whether overwinter soil moisture storage could be feasibly increased and whether this would benefit dryland crop yield in the Brown soil zone.

This project was initiated in August, 1990 and, although it was intended to continue until 1993, it was decided that after 1991 events and results, no further meaningful information could be obtained from this study. It will therefore be concluded early in 1992. This report summarizes the activities and results of the eighteen months of the study, and a complete report is available from the Conservation and Development Branch.

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## METHOD

### Site Description

The site for this study is located east of Wrentham, Alberta, approximately 70 km southeast of Lethbridge. The area contains Orthic Brown Chernozemic soils mapped as Maleb-Cranford, and inspection of cores indicated that the soils were derived from glacial till. The plots are located in NE 3- 7-15-W4, a field that has a 3-year wheat, 1-year fallow rotation. The field has undulating topography.

### Study Design

The study objectives were to evaluate the effectiveness of the Dammer-Diker on improving the amount of available soil moisture and crop yield and to identify the costs associated with the operation of the implement. Statistically, the study was designed to test the hypothesis that there is no difference in total available soil moisture within the top metre among plots treated with the Dammer-Diker and those left untreated. The field was divided into twelve plots in which two treatments and a control (untreated) were replicated four times. The plot layout is a simple randomized design. The treatments with the Dammer-Diker included a set of plots that were both ripped and pocketed, and a set that was ripped, but not pocketed. It is the opinion of the authors that the visible improvements in crops on fields treated with the Dammer-Diker during demonstrations were primarily due to the ripping action, and that the pocketing of the soil produces less benefit. A more detailed presentation of the methods is available in the report.

## RESULTS

Because of the extremely dry soil conditions at the time the treatments were applied, the paddles controlled the depth of ripping on the ripped and pocketed plots by holding up the unit and restricting the penetration of the rippers to 250 mm. At the plots which were ripped only, the ripper penetration was manually controlled in order to maintain the same ripping depth. This added to the operation time.

The precipitation during the winter was 116% of the 30-year average (Table 1). The snowcover in January ranged from 0 to 19 cm, with the deepest cover on the north half of the site. The snow cover had completely disappeared when the measurements in February and March were

Table 1. Precipitation (mm) recorded at the site from August 1990 through September 1991. Longterm monthly averages are also presented. October through March data is from the Foremost climate station, 30 km east of the study site.

| | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|
| 1990/91 | 25 | 72 | 136 | 10 | 7 | 1 | 251 |
| 1975-90 Av | 24 | 53 | 54 | 28 | 36 | 34 | 199 |
| | Oct | Nov | Dec | Jan | Feb | Mar | Total |
| 1990/91 | 5 | 36 | 44 | 7 | 20 | 18 | 130 |
| 1951-80 Av | 14 | 16 | 18 | 23 | 20 | 21 | 112 |

taken. Following the overwinter monitoring, the frequent rains during May and June delayed seeding on this field until the end of June. The crop matured in September, however the producer suddenly changed the harvest schedule and harvested the crop two weeks early without informing our staff. As a result no yield samples could be taken, eliminating the opportunity to reach the second and third objectives and limiting the success of evaluating the first.

Soil Moisture

Overwinter gains in soil moisture are taken as the difference in moisture contents between September 28, 1990 and March 27, 1991. The moisture gains within the top metre for each plot are summarized in Table 2. In the top metre of soil, all plots gained at least 33 mm of soil moisture and most gained almost 50 mm. The highest gains occurred in two of the ripped-only plots, where over 80 mm of soil moisture was added over winter. Comparison of the soil moisture gains in the individual plots as well as the means and standard deviations in Table 2 indicates that although the highest gains were found in the ripped-only plots, that treatment also had the highest variability. An analysis of variance was performed on the gains and the results showed that the null hypothesis could not be rejected, primarily due to the high degree of within-treatment variability.

Table 2. Overwinter soil moisture gains (mm) within the top metre for each treatment during 1990 - 91.

| | SOIL MOISTURE GAIN (mm) | | |
|---|---|---|---|
| | RIPPED & POCKETED | RIPPED | CONTROL |
| | 38.5 | 81.0 | 58.0 |
| | 47.8 | 83.5 | 45.5 |
| | 33.3 | 44.0 | 53.8 |
| | 50.5 | 35.0 | 41.3 |
| Mean | 42.5 | 60.9 | 49.7 |
| Std. Dev. | 7.6 | 25.0 | 8.0 |

The undisturbed (control) sites converted an average of 50 mm of the 130 mm of overwinter precipitation to rootzone soil moisture, a storage efficiency of 38%. The storage efficiency ranged from 26%, in a ripped and pocketed plot, to 64% in one of the ripped plots. Studies where ripping and snow management were used together show that overwinter soil moisture gains on ripped areas can be up to twice as much as that on undisturbed fields under similar soil conditions (Gray et al, 1990; McConkey et al, 1988). They conclude that use of snow trapping with ripping is essential for maximizing overwinter moisture gains. The literature also reports a progressive decrease in the impact of ripping in the years following the treatment, although this does not necessarily mean that the fields return to pre-treatment conditions. A more detailed explanation is presented in the report.

An examination of the soil sample analysis data provided little information that could explain the high variability of the overwinter soil moisture gains. No clear trend or relationship exists between

texture and overwinter soil moisture gain. Other factors, including salinity, SAR, snow accumulation, and initial soil moisture content could not directly account for the variability within treatments.

One possible explanation of the variability observed in the top metre may be that the Dammer-Diker did its job too well. Four plots, one control, one ripped, and two ripped and pocketed treatments, had increases of at least 10 mm in soil moisture at depths below the top metre. The gains were observed January 30, following the major snow events of November and December and a warm period in mid-January. The shattering nature of the ripping promotes rapid downward water percolation. Since the ground was dry, conditions favored extensive shattering of the subsoil which may have resulted in snowmelt moving beyond the 1.25 m depth of measurement during January.

There is also a high probability that water movement occurred in some plots without being detected. The access tubes were located in the areas between the ripping tracks. It was thought that the probe would detect wetting in the fractured areas immediately around the tube, however it is possible that direct, rapid downward movement of water through fractures occurred only within the ripping tracks at some plots without wetting the area around the access tubes. This would explain the low moisture gains observed at some of the treatment plots.

<u>Operating Costs</u>

Operating costs were calculated by using the operating time measured by the producer and custom charge-out rates for a suitable tractor, as determined by the Alberta Agriculture (Loree, 1991). The result was a total cost of operation is $68.50 per ha. Labor costs were 22% of the total, based on a rate of $6.00 per hour, and tractor costs were 59% of the total, based on a tractor with a 90 horsepower PTO, the minimum power requirement for pulling the dammer-Diker. Rental costs for a Dammer-Diker were not available but the rental rate for rippers of similar cost was calculated as $13.00 per ha. This was based on a rate of $65.00 per day and 12 hours to cover 5 ha. The cost of a new Dammer-Diker was quoted as $6,600.00 in 1991. Since post-treatment field work was not required, no cost has been considered.

It should be noted that extra time was required to maintain accurate depth control on the ripped plots, and this is included in the total cost. It is likely that operating the Dammer-Diker over a large field, rather than the 2.4 ha field in which this study was located, would reduce the cost per ha to a small degree. The cost of operation is slightly lower than the cost of deep ripping ($75.00 per ha, with no follow-up field work), based on rates determined by Alberta Agriculture (J. Lickacz, personal comm.).

<u>Yield</u>

Yield responses were not attainable, however data from ripping studies is available and under similar conditions may be analogous. Table 3 presents information by Gray et al (1990) from a ripping study in Kerrobert, Saskatchewan, where stubble was used to trap snow for soil moisture conservation, and soil and crop conditions were similar to those of this project. The Dammer-Diker shanks rip to 400 mm depth and have a 0.9 m shank spacing, which is the same as one of the rippers used by Gray et al (1990). Unfortunately due to the very dry soils at Wrentham, ripping depth was 250 mm, which may weaken the assumption.

Table 3 shows average yield data from several plots in the study area. The combination of ripping and stubble management resulted in yield gains for continuous spring wheat that would be significant enough to justify the cost of ripping. The yield increases must be considered a potential response however, due to the sampling methods used in the Gray et al (1990) study and the shallow ripping depths in this study.

Table 3. Yield responses of spring wheat to ripping, under similar conditions to those of this study. (Gray et al 1990).

| Age of Treatment | Rain mm | Yield Gain kg/ha (difference from control) | bu/acre |
|---|---|---|---|
| 1st yr | 110 | 1435 | 21 |
| 2nd yr | 106 | 1335 | 20 |
| 3rd yr | 122 | 855 | 12 |
| 4th yr | 100 | 510 | 8 |
| | Average | 1034 | 15 |

If the price for spring wheat is $3.00 per bushel, average yearly yield gains of 9 bu per ha (3.6 bu/ac) are required to recover the costs over a three year period. This assumes that the field is continuously cropped to spring wheat, and annual interest rates are 10%.

## CONCLUSIONS

The study did not provide any conclusive evidence that the Dammer-Diker provided a benefit to soil moisture or crop yield. The main result from this study is that although two sites showed considerable increases in soil moisture following treatment with the Dammer-Diker it is not significant enough to reject the null hypothesis, due to the high amount of variability in soil moisture conditions at this site. There is evidence to suggest that the Dammer-Diker did improve soil hydraulic conductivity and snowmelt rapidly percolated beyond the rootzone and into the deeper subsoil as a result of the treatments, however they still did not add substantially to the rootzone reserve in this field.

The cost of operating the Dammer-Diker on the 2.4 ha. field is $68.50 per ha. While costs would likely be slightly lower for a large field, they would still be slightly lower than the cost of $75.00 per ha for deep ripping. Considering these costs, an average yield gain of 9 bu per ha is required over the following three years to pay for the operation. Ripping studies under similar soil and crop management conditions suggest that justifiable gains are attainable.

All sites had tall standing stubble retained on the surface to trap snow and this likely contributed to soil moisture storage. If storage efficiencies of 64% could be consistently attained using the Dammer-Diker, it would allow farmers to reduce summerfallowing. When

treating a field with a ripper or a Dammer-Diker it is strongly recommended that stubble be managed to trap as much snow as is feasibly possible. This is especially important in the Brown or Dark Brown zone, where capturing snowmelt, when it occurs, for soil moisture storage can make the difference between adequate and inadequate yield responses following treatment.

To fully assess the suitability of the Dammer-Diker, studies are still required at more sites, each evaluating the results of the Dammer-Diker treatments over a time period of at least four years. Because it basically performs two soil operations, ripping and pocketing, the question of whether it outperforms conventional ripping under Alberta conditons remains unanswered. Although the impact on crop yield is perhaps the most important factor that needs to be evaluated, few studies have investigated the impact on overwinter soil moisture gain. The potential for ripped fields to convert up to twice the snowmelt into stored soil moisture than undisturbed fields must be examined more closely to see if it applies to southern Alberta conditions.

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# ON-FARM WATER MANAGEMENT FOR ROTATIONAL GRAZING

S. Ali[1], B. Berg[2], A. Khan[3], and P. King[4]

## INTRODUCTION

This demonstration project was undertaken in 1991 to demonstrate the following three (3) major components of the project:

(A) Water consolidation within a small watershed of rolling topography to provide and maintain a secure and good quality water supply for "rotational grazing system" on a quarter section pasture.

(B) A grazing management system incorporating (a) rotational grazing using no fixed field sizes (b) pasture rejuvenation using rest and fertilizers and (c) extended grazing season strategies for perennial forage crops.

(C) Demonstrate an effective, economical and practical insect pest management.

The data collection and analysis on this project will continue to the end of 1995.

## METHODS

This demonstration project is owned by Mr. Robert (Bob) Prestage and is located 8 km west of Camrose, Alberta, on SE 1/4 Sec 35- Tp 46-Rg 21- W4. The methodology undertaken to demonstrate the three (3) objectives was:

1. <u>Works Completed In 1991:</u>

(i) Small potholes and depressional areas were consolidated into two dugouts by means of open ditches ( grassed waterways ) and buried plastic tubing were used where open ditches were not economically feasible because of the rolling land. The design and location of the dugouts were based upon a two years water supply in drought years and the pasture field plan for the grazing system. The dugouts were fenced and a solar pump and trough system was built to provide each pasture with its own water source. Cattle will not have direct access to the dugouts.

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(ii) A 24 hectares (60 acres) cultivated field was seeded to alfalfa and meadow brome grass in the spring of 1991. The perimeter fence and interior fences were removed and/or reconstructed. The forage was harvested as hay and green feed and grazed lightly in late fall.

(iii) This demonstration project was used to study the impact of water consolidation on mosquito population. The data was collected during the two month period of June and July, 1991. Twelve (12) temporary water bodies constituting a water surface area of 31,576 square metres were eliminated in this project as part of water consolidation. These temporary water bodies represented 29 % of the total water bodies on this quarter section of land and were in fact the rich breeding habitat for mosquitoes. Twice the number of mosquito larvae were found in similar nearby water bodies. Water consolidation resulted in a permanent reduction (68 %) of the mosquito breeding habitat. An estimated 9,530,334 mosquito larvae were prevented from hatching during the months of June and July. It could be speculated that this 68 % reduction in mosquito population could result in upto 5 % more milk production if this were a dairy operation. This has not yet been documented in an Alberta environment.

The cost of source reduction or mosquito habitat reduction as a means of controlling mosquitoes in grazing pasture is not known. Future studies are being planned to study in detail the cost of providing an improved grazing environment for cattle in native pastures.

2. <u>The Future Work Plan:</u>

The future activities to meet the objectives of the above mentioned three components of this demonstration project are summarized below:

<u>Component "A"</u>

(i) Monitor the quality and quality changes of water in a dugout in an intensive grazing project with a pumped water supply and compare this information to a similar dugout (located in the vicinity of the project) with direct cattle access to its water. The information collected will provide some base-line data for water quality in well managed pasture dugouts.

(ii) Monitor the quantity of water consumed by cattle for inclusion in the production data collected.

(iii) Monitor the grassed waterways to see how well they hold up to an intensive rotational grazing system.

(iv) Install and monitor weather station to collect data on (a) Daily Precipitation and Intensity/Duration from heavy storms (b) Snowmelt Runoff Yield (c) Daily Temperatures (d) Relative Humidity and (e) Water Balance, to be used in the final analysis.

Component "B"

(i) Demonstrate the efficacy of rest combined with fertilizer in returning old grassland to higher productivity.

(ii) Demonstrate a grazing system with no pastures of permanent or fixed size.

(iii) Demonstrate the use of swathe grazing perennial forage to extend the grazing season and reduce winter feed costs.

Component "C"

(i) Evaluate the effectiveness of a systemic insecticide as a contact insecticides to control blood feeding insects (mosquitoes, horn flies) and non-blood feeding insects (face flies).

(ii) Study the impact of continuous summer long treatment of systemic insecticide on cattle lice and warbles so that spring and fall treatments could be eliminated.

(iii) Incorporate broad spectrum pest control technique with rotational grazing system and water management.

# EVALUATION OF SPRING BACKFLOOD IRRIGATION IN CENTRAL ALBERTA

J. Prochnau, S. Ali, and N. MacAlpine[1]

## INTRODUCTION

Spring backflood irrigation involves flood irrigation on frozen soils using water from snowmelt. Because the area is flooded with water which is warmer than the frozen soil, the soil often thaws more quickly, allowing earlier field operations. It is an opportunity to recharge root zone soil profiles with moisture before the growing season begins. In the south of Canada's prairies, spring backflood irrigation has been used for many years. However, in central and northern Alberta, snowmelt is generally regarded as excess water and a nuisance to get rid of as quickly as possible.

Forage and cereal crops often suffer from drought stress later in the summer when moisture is used up in the root zone. Also, the pressures to move large volumes of water and erosive rates of snowmelt off the farm in the spring result in high capital costs to upgrade off-farm drainage systems, allowing earlier field operations.

Both factors justified a well documented demonstration of the on-farm benefits of managing spring smowmelt to recharge root zone soil moistures and the off-farm benefits of reduced flood peak flowrates and erosion protection. The Golden Glow Spring Backflood Irrigation Demonstration, as the project is currently known, was initiated by the Conservation and Development Branch in 1989 and has been continued on a yearly basis since that time. This report summarizes the activities and some results since that time.

## SITE DESCRIPTION

The Golden Glow Spring Backflood Irrigation Demonstration in the County of Leduc near Millet, is a combination of spring backflood irrigation and controlled drainage operations on what was previously a seasonal wetland. The project's 811 hectares (2,000 acres) of contributing watershed area delivers approximately 94,850 cubic metres (65 acre-feet) of runoff water into the backflood slough of 21.9 hectares (54 acres). In July of 1989, the outlet channel (500 metres long) was reshaped and reconstructed to meet the minimum demonstration standards. A ditch berm was built in the channel to accommodate the stop log control structure on a 400 mm diameter (18 inch) currugated metal pipe. Mini-slab erosion-control blocks were also installed over the control structure's berm to provide the overflow erosion protection and farm crossing facilities.

Two plot sites were selected in 1990, an upland plot west of the slough area in sandy loam soil and a backflood plot in the backflood slough of muck soil. The two plot sites were established to evaluate forage varieties that will work relatively better under backflood conditions. The varieties chosen were two legumes (alfalfa and alsike

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clover) and four grasses (timothy, bromegrass, creeping foxtail, and reed canary grass). Each variety was seeded 3 times per plot. The seeding rates are identified in Table 1. The plots were seeded on June 19, 1990 using a Brillon grass seeder.

Table 1. Golden Glow Forage Plot Seeding Rates in 1991

| FORAGE VARIETY | SEEDING RATE (lbs/ac) |
|---|---|
| Peace Alfalfa | 8 |
| Alsike Clover #1 | 6 |
| Climax Timothy | 4 |
| Carlton Brome | 10 |
| Venture Reed Canary Grass | 6 |
| Creeping Foxtail #1 | 10 |

A fully functioning weather station was set up at the site on June 1, 1990 to properly record the intensity and duration of rainfall in evaluating infiltration and runoff from storms. It consisted of a manual type B rain gauge, a tipping bucket rain gauge, and a Stevenson Screen which housed a temperature and relative humidity sensor and a datalogger.

## METHOD

Soil tests were conducted on the plot sites on May 14, 1990 to establish nutrient and micronutrient levels in the soil. These tests were important in determining the amount of fertilizer applied to the plots. At the end of the 1990 growing season, a visual inspection of the plots as well as plant counts were carried out.

Thermocouples were installed in the fall of 1990 in replicates of 4 nests per plot in both the upland and backflood plots. During spring runoff in April and May of 1991, soil temperatures were recorded at depths of 5, 10, 20, 40, 60, 80, and 100 cm. Frost recession using a soil probe was also measured when applicable during each monitoring event. Neutron probe access tubes were installed during the spring of 1991. Soil moisture was monitored later in the summer and again in the fall.

## RESULTS

There was no significant flooding or channel erosion noted similar to that when snow dams broke loose in the spring of 1989. With the demonstration's control structure operating there were dramatic different effects downstream. The control structure was overtopped one day in 1990 and 1991 and the Minislabs did their job in protecting the structure from washing out. It took 3 days for the 54 acres of backflooding to drain dry in 1991 compared to 5 hours in 1989 when there was no control structure.

On June 19, 1990 seeding of the plots was completed but heavy rains waterlogged the backflood plots. The upland plot had near ideal moisture conditions for germination in June and July while the backflood plots had some very moist conditions. At the end of the growing season,

a visual inspection of the plots as well as plant counts were carried out. There was almost a night and day contrast between the way the different forage varieties germinated in the upland sandy loam plots compared to the backflood muck soil plots in 1990. At the end of the growing season, alfalfa followed by bromegrass appears to be the best forage choices for the upland area. Reed canary grass followed by creeping foxtail appears to be the best forage choices for the wetland area. Timothy showed that it prefers well drained but moist soils as its germination initially was spotty but its growth was vigorous. Alsike clover did not germinate well in either plot. By the end of the summer, all forages had established well in both plots and were ready to show the effects of full backflooding.

Water was left on the backflooded area for 23 days in 1991, in an attempt to draw the frost from the backflood area. Thermocouple readings for soil temperature and measurements of frost recession in the spring of 1991 indicated that the frost was removed quicker from the upland plots. When the water was released the frost was only removed to approximately 30 cm (12 inches) in the backflood plots compared to 90 cm (36 inches) in the upland plots. High soil moistures in the backflood area the previous fall probably resulted in substantial ice lense forming in the peat soil.

The alfalfa, clover and timothy survived very well in the upland plot. Alfalfa did not survive the long flood duration in the backflood plot. Creeping foxtail survived the best with a 30 cm (12 inches) of growth 8 days after the backflood water was removed. The second best forage in terms of initial regrowth was the brome. Native hays and sedges germinated and provided competition to any forage that had germinated poorly the year before with a thin stand.

A detailed runoff modelling and flood routing study was done along with an economic analysis of the project and the downstream watercourse. Both showed the project had significant benefits. The economic analysis report is also near completion.

## SUMMARY AND CONCLUSIONS

The control structure provided sizable downstream benefits as well as being a low cost structure to be used for water management. The controlled drainage aspect of the project is a benefit to the downstream acreage owners who need some form of flood protection. The off-farm benefits of controlled drainage were determined by comparing 1990 and 1991 data with 1989's uncontrolled drainage information. The benefit-cost analysis is being summarized in a separate economic report.

The report has been done from two perspectives: a farm financial (private) analysis looking only at on-farm costs and benefits; and a socio-economic (public) analysis that takes into account not just on-farm but also all off-farm development costs and associated benefits. The results of the farm financial analysis show that for the "expected" scenario there should be a Benefit/Cost ratio of 3.6 where "expected" is for a typical year once the project is operational. The results of the public analysis show a B/C ratio of 3.9. Other scenarios were also run (providing "best" and "worst" case scenarios) and all of them showed that this project is economically justified from both public and private perspectives.

The tolerance of various forage varieties to spring flooding needs to be extended. The forages in place and the native hays and sedges that established in 1991, need to be followed up. The feed value of the native hays and sedges needs to be monitored to see if their protein and energy levels are as good or better than those of tame grasses. Competition from the native hays and sedges may be more of a problem than water tolerance if the forage does not germinate strongly in the establishment year. New varieties that are spring flood tolerant and are of a high feed quality need to be tested. As a result, a new Swedish white clover variety was seeded into the upland and backflood plots in the fall of 1991.

Early spring rains improved the soil moisture levels in the upland plot to a point where soil moisture was not a limiting factor in 1991. There needs to be further analysis on whether soil moistures can be significantly improved under a backflood setting. The first year of full backflooding on this project had high soil moistures from the previous fall with no forage to use the moisture causing slow soil thawing. There is another backflood irrigation demonstration project near Barrhead that we monitor in spring. It has similar soil conditions but has a well established forage crop. With the well established forage crop there is good infiltration in spring and faster soil thawing in the backflood area than the surrounding upland area.

Based on the information gathered to date there needs to be well established forages before proceeding with backflood operations to accelerate spring soil thawing. New varieties of forage need to be tested and the Golden Glow project has the right conditions to monitor these issues.

A copy of the Golden Glow Spring Backflood Demonstration Annual Report for 1989, 1990, or 1991 and the Economic Analysis of the project can be obtained by contacting the Conservation and Development Branch in Edmonton.

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# FIELD SHELTERBELTS: A SURVEY OF ATTITUDES OF AGRICULTURAL FIELDMEN AND FIELD SHELTERBELT OWNERS

J. Timmermans[1] and M. Quantz[2]

## INTRODUCTION

The signing of the Canada-Alberta Soil Conservation Initiative (CASCI) in July of 1989 initiated a renewed emphasis on the use of field shelterbelts for soil conservation, as well as other benefits. Although trees have been available to Alberta farmers for many years, field shelterbelts have not been expressly promoted or evaluated in Alberta. In January of 1990, a telephone survey was conducted, of agricultural fieldmen and farmers who had field shelterbelts. The objectives were to

1. obtain from the field staff, names and locations of farmers who own field shelterbelts.
2. learn from the field staff, their opinions, wants and needs relative to field shelterbelts
3. learn from producers, their opinions of advantages and disadvantages of field shelterbelts, and their suggestions for improvement of field shelterbelt programs.

## METHODS

Forty-seven agricultural fieldmen were contacted. Only six indicated they had plans for field shelterbelt demonstrations during the upcoming year. The majority did indicate plans to establish demonstrations of a variety of aspects in future years. Most fieldmen indicated the need for information regarding species and economic/agronomic implications of field shelterbelts in Alberta. The most negative responses were expressed by those in irrigated districts. Most of the fieldmen contacted readily supplied names of producers for us to contact, and asked to be kept informed of overall survey results as well as responses from farmers in their own districts.

A total of 158 farmers from all six Alberta Agriculture regions (Figure 1.) were called. They were asked what they thought were the advantages (Table 2), disadvantages (Table 3), and their suggestions as to how field shelterbelt numbers might be increased (Table 4). They were also asked about their own field shelterbelts, including species, age, orientation and length.

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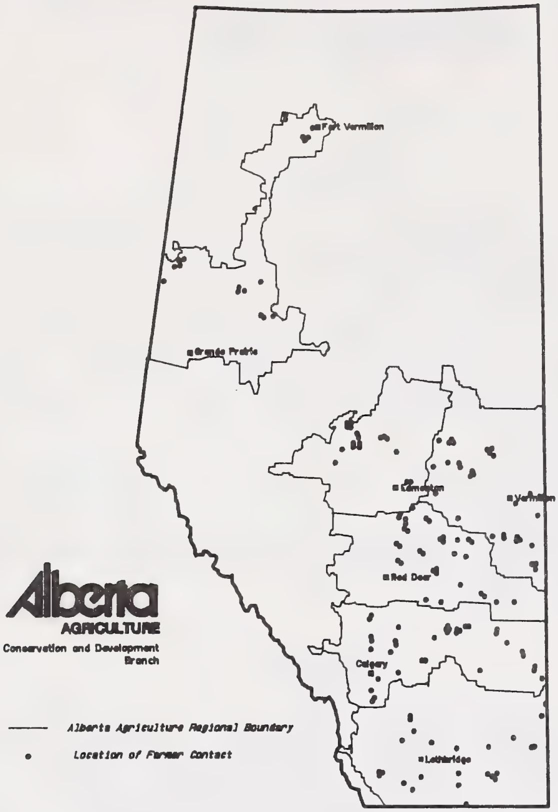


Figure 1. Distribution of farmers contacted

## RESULTS

Tables 1 through 4 show the ranking and distribution of answers to the questions relating to species, advantages, disadvantages and suggestions, respectively. Note that neither the total columns nor the percent columns add up to the total number of farmers or 100%, because many respondents offered more than one answer per question. Similarly, some respondents did not offer answers for all the questions. Following are some of the significant trends which appeared:

Half of all shelterbelt owners surveyed have poplar and/or caragana, making these by far the most common species planted. Poplar was quite common in all regions except V, and caragana was most popular in regions I to III.

The four most frequently stated advantages of field shelterbelts are reduced wind, trapped snow for increased soil moisture, improved aesthetic value and enhanced wildlife habitat. All other advantages given were far less frequent than any of these first four.

The inconvenience of farming around shelterbelts was the most common disadvantage given. Interestingly, the fifth most commonly given disadvantage was "none". There were more disadvantages listed than advantages, but of 27 listed, 20 were mentioned by 10% or fewer of the number of respondents.

Field shelterbelt owners readily supplied suggestions to help increase the number of trees planted. Here, four suggestions stood out clearly as the most often given. They are the supply of free and ample trees, the provision of assistance in the form of labor and equipment from the municipality, more promotion to create awareness of the benefits, and incentives. These four suggestions were 161 out of a total of 210 responses which totalled 31 different suggestions.

Not all the responses were positive. Some farmers who had trees beyond maturity in age, and were faced with the job of removing them stated that more frequent cropping would be a better soil conservation practice than planting shelterbelts again.

The majority of field shelterbelts in Region I were north-south, with some in the eastern districts aligned east-west. In the other five regions of the province, the two orientations were roughly equivalent in number. The majority of the shelterbelts were planted, except in Region VI where half the respondents had native shelterbelts. The average age of the shelterbelts was 20 years or more.

More than one quarter of the respondents owned one mile of trees or less. Approximately half owned more than 3 miles. In Regions I to IV, more than half the farmers had more than one shelterbelt per field, while this was more rare in Regions V and VI.

## DISCUSSION AND CONCLUSIONS

This survey was not of a random sample, because only farmers were contacted who had field shelterbelts on their farms. However, both the fieldmen and farmers provided useful information for staff designing and working with field shelterbelt programs. Although most were quick to acknowledge the effort and inconveniences of field shelterbelts, most were also felt positive about their own trees and about this survey. The suggestions offered were most interesting in that they probably point out some frustrations farmers have had in their own shelterbelt projects. These may include inadequate supply, species or pricing policies of the past. Of the four most frequently made suggestions, the field shelterbelt program expanded through CASCI funding is currently and directly addressing the top three. The renewed emphasis on field shelterbelts is positively influencing the level of activity by fieldmen and agricultural service boards, and also by farmers requesting more information, and in planting greater numbers of field shelterbelts.

Table 1. Species of trees in field shelterbelts

| | Regions 1 | 2 | 3 | 4 | 5 | 6 | Total | Percent |
|---|---|---|---|---|---|---|---|---|
| poplar | 11 | 15 | 20 | 16 | 5 | 14 | 81 | 51.3 |
| caragana | 21 | 27 | 13 | 8 | 3 | 8 | 80 | 50.6 |
| spruce | 4 | 4 | 13 | 16 | 14 | 5 | 56 | 35.4 |
| willow | 3 | 3 | 11 | 9 | 7 | 7 | 40 | 25.3 |
| ash | 7 | 2 | 2 | 1 | 6 | | 18 | 11.4 |
| maple | 4 | 3 | 1 | 5 | 4 | 1 | 18 | 11.4 |
| pine | 1 | | 4 | 6 | 2 | 1 | 14 | 8.9 |
| lilac | 1 | 2 | 3 | 4 | 1 | 1 | 12 | 7.6 |
| elm | 5 | 1 | 1 | 1 | 1 | | 9 | 5.7 |
| honeysuckle | | 1 | | 3 | | | 4 | 2.5 |
| larch | | 1 | | | 2 | | 3 | 1.9 |
| chokecherry | | 1 | | 2 | | | 3 | 1.9 |
| mayday | | | 1 | 1 | 1 | | 3 | 1.9 |
| Russian olive | 2 | | | 1 | | | 3 | 1.9 |
| fir | 1 | | | | | | 1 | 0.6 |
| dogwood | | | | 1 | | | 1 | 0.6 |
| aspen | | | | | 1 | | 1 | 0.6 |
| Total farmers telephoned | 24 | 35 | 33 | 30 | 18 | 18 | 158 | |

Table 2. Advantages of field shelterbelts

| | Regions 1 | 2 | 3 | 4 | 5 | 6 | Total | Percent |
|---|---|---|---|---|---|---|---|---|
| wind reduction | 21 | 26 | 27 | 20 | 13 | 12 | 119 | 75.3 |
| traps snow | 18 | 30 | 25 | 19 | 11 | 8 | 111 | 70.3 |
| aesthetic value | 12 | 16 | 17 | 12 | 12 | 9 | 78 | 49.4 |
| wildlife | 11 | 13 | 9 | 6 | 5 | 4 | 48 | 30.4 |
| protects crop | | 1 | 2 | 5 | 3 | | 11 | 7.0 |
| protects cattle | 1 | 5 | 1 | 2 | | 1 | 10 | 6.3 |
| less water erosion | 1 | | 1 | 4 | 1 | 1 | 8 | 5.1 |
| privacy | 1 | | | 1 | 2 | | 4 | 2.5 |
| none | 1 | 1 | | | | 2 | 4 | 2.5 |
| division between fields | | | | | 1 | 3 | 4 | 2.5 |
| holds water table | | | 1 | | 1 | | 2 | 1.3 |
| less dust from road | | | | 1 | 1 | | 2 | 1.3 |
| traps blowing weeds | 1 | | | | 1 | | 2 | 1.3 |
| reduces soil salinity | 1 | | | | | | 1 | 0.6 |
| Total farmers telephoned | 24 | 35 | 33 | 30 | 18 | 18 | 158 | |

Table 3. Disadvantages of field shelterbelts

| | Regions | | | | | | Total | Percent |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | | |
| hard to farm around | 8 | 15 | 13 | 14 | 8 | 3 | 61 | 38.6 |
| takes moisture from crop | 6 | 11 | 7 | 2 | 3 | 6 | 35 | 22.2 |
| work to establish/maintain | 8 | 10 | 2 | 5 | 6 | 2 | 33 | 20.9 |
| swath drys slower | 3 | 2 | 6 | 4 | 5 | 6 | 26 | 16.5 |
| none | 2 | | 6 | 7 | 3 | 1 | 19 | 12.0 |
| spray harms trees | 6 | 5 | 3 | 2 | | | 16 | 10.1 |
| overhang/dead trees | 2 | 5 | 4 | 2 | | 3 | 16 | 10.1 |
| weed growth | 2 | 1 | 5 | 2 | 3 | 2 | 15 | 9.5 |
| land lost | 1 | 5 | 2 | 2 | 1 | | 11 | 7.0 |
| diseases/insects in trees | 2 | | 4 | 2 | 1 | | 9 | 5.7 |
| water erosion in spring | | 2 | | | | 7 | 9 | 5.7 |
| cattle | 3 | 2 | 2 | | | | 7 | 4.4 |
| trees sucker | 1 | 2 | 1 | | | 2 | 6 | 3.8 |
| causes snow drifting | 1 | 3 | | 1 | | | 5 | 3.2 |
| traps blowing weeds | 1 | 1 | | 1 | | 1 | 4 | 2.5 |
| trapped snow breaks fences | | 3 | 1 | | | | 4 | 2.5 |
| taken for Christmas trees | | | 1 | | 2 | 1 | 4 | 2.5 |
| wildlife | 2 | 1 | | | | | 3 | 1.9 |
| shades crop | | | | 1 | 1 | | 2 | 1.3 |
| hunters | 2 | | | | | | 2 | 1.3 |
| brome grass spreads ergot | | | | | 1 | | 1 | 0.6 |
| fire hazard grass in trees | | | | | 1 | | 1 | 0.6 |
| no snow in middle of field | | 1 | | | | | 1 | 0.6 |
| pivot irrigation | | 1 | | | | | 1 | 0.6 |
| older trees no low branches | | | | 1 | | | 1 | 0.6 |
| near trees crop lodged | | | | 1 | | | 1 | 0.6 |
| long term planning | 1 | | | | | | 1 | 0.6 |
| Total farmers telephoned | 24 | 35 | 33 | 30 | 18 | 18 | 158 | |

Table 4. Suggested ways to help increase shelterbelt numbers

| | Regions 1 | 2 | 3 | 4 | 5 | 6 | Total | Percent |
|---|---|---|---|---|---|---|---|---|
| free trees, ample supply | 12 | 10 | 12 | 6 | 7 | 10 | 57 | 36.1 |
| labor/equipment from county | 4 | 11 | 5 | 12 | 3 | 3 | 38 | 24.1 |
| promotion, awareness | 3 | 5 | 4 | 9 | 10 | 3 | 34 | 21.5 |
| incentives | 2 | 7 | 8 | 8 | 4 | 3 | 32 | 20.3 |
| trees removed must be replaced | | | 4 | 1 | 2 | 2 | 9 | 5.7 |
| determine best species for area | | 1 | 1 | 1 | 1 | | 4 | 2.5 |
| mandatory planting (law) | 1 | 1 | 1 | 1 | | | 4 | 2.5 |
| demonstrations | | | 1 | 1 | 2 | | 4 | 2.5 |
| charge for trees/more appreciated | | | | 3 | | 1 | 4 | 2.5 |
| courses in care/maintenance | 2 | 1 | | | | | 3 | 1.9 |
| trees by roads/reduce drifting | | 1 | 1 | 1 | | | 3 | 1.9 |
| distribute earlier/better timed | 1 | 1 | | | | | 2 | 1.3 |
| transplant older trees | | | | 1 | | 1 | 2 | 1.3 |
| other shelterbelt species | 1 | | | | | | 1 | 0.6 |
| plant trees behind snow fences | 1 | | | | | | 1 | 0.6 |
| plant with Fish and Wildlife | 1 | | | | | | 1 | 0.6 |
| herbicide research | | 1 | | | | | 1 | 0.6 |
| better establishment technology | | 1 | | | | | 1 | 0.6 |
| approach young farmers | | | 1 | | | | 1 | 0.6 |
| data showing production increases | | | 1 | | | | 1 | 0.6 |
| fast growing trees available | | | | 1 | | | 1 | 0.6 |
| more fruiting trees available | | | | 1 | | | 1 | 0.6 |
| pros/cons in tax notices/gas bills | | | | 1 | | | 1 | 0.6 |
| county selective in removal | | | | 1 | | | 1 | 0.6 |
| elevator agents/good farmer contact | | | | 1 | | | 1 | 0.6 |
| farmer cooperative hire someone | | | | | 1 | | 1 | 0.6 |
| lobby group set county regulations | | | 1 | | | | 1 | 0.6 |
| no roadside spraying | | | 1 | | | | 1 | 0.6 |
| trees that use less moisture | | | | 1 | | | 1 | 0.6 |
| plant in fencelines | | | | | 1 | | 1 | 0.6 |
| conservation money on trees | 1 | | | | | | 1 | 0.6 |
| Total farmers telephoned | 24 | 35 | 33 | 30 | 18 | 18 | 158 | |

# WIND REDUCTION BY CARAGANA FIELD SHELTERBELTS IN SOUTH CENTRAL ALBERTA

J.G. Timmermans[1], B.R. Hamman[2], C.H. Sprout[1], I.A. Laslo[1]

## INTRODUCTION

Field shelterbelts historically have been characterized by porosity, which is at best objectively defined via photographic techniques (Heisler and Dewalle, 1988). The coefficient of resistance, derived from aerodynamic properties, provides a less subjective and more replicable method of characterizing field shelterbelts (Wilson et al., 1990).

Caragana arborescens is a leguminous shrub. It is drought tolerant and withstands chinooks (i.e. mid-winter thaw). For these reasons, caragana is the most frequently planted field shelterbelt species in Alberta.

During the summer and fall of 1991, the following hypotheses were tested in field experiments in south-central Alberta: caragana field shelterbelts 1) reduce wind velocity (U) in the lee of the field shelterbelts; and, 2) in-leaf field shelterbelts have a greater wind-reducing capability than out-of-leaf field shelterbelts, but both reduce U. A further objective was to characterize the aerodynamic resistance coefficient of the caragana field shelterbelts both in-leaf and out-of-leaf.

## MATERIALS AND METHODS

### Sites

Wind velocities (U) were measured behind six in-leaf and three out-of-leaf single row caragana field shelterbelts with adjacent leeward fields in either cultivated or sprayed-stubble fallow. All the sites were in south-central Alberta east of Calgary. The age of the caragana ranged from 16-40 years. The height of the field shelterbelts ranged from 2.7-4.0 m, while the crown width ranged from 3.8-5.6 m. Six field shelterbelts ran east to west and one ran north to south (Fig. 1).

### Equipment and experimental design

Wind reduction was recorded for each wind direction but without discrimination with respect to approaching U or atmospheric stratification. Seven Campbell Scientific (CS) model 014A met-one wind

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speed sensors were set up at height (z)=1 m in a line perpendicular (⊥) to the belt. The spacing of the anemometers was a multiplicative function of belt height (H) (i.e. 1, 3, 5, 7, 10, 15, and 25). A wind direction sensor (CS model 024A) was placed at 25H. Each of the anemometers was connected to a CS-CR10 datalogger. The datalogger registered instantaneous U every 30 seconds and calculated an average every 10 minutes. Readings were taken at each site for about one week.

Statistical analysis

Relative wind speeds at the different distances ($RWS_x$) were calculated by dividing those velocities by that of $U_{25H}$. The assumption was that $U_{25H}$ represented an undisturbed location. The result was a dimensionless value, which could be used for comparisons. (Bean et al., 1975).

Wind direction was recorded in degrees. The compass was divided into 16 quadrants, each quadrant included 22.5° (e.g. N was $-11.25^{\circ} \leq \perp \leq +11.25^{\circ}$).

The effect of distance from the shelterbelt on RWS was analyzed (proc GLM on SAS). The model was run a second time to analyze the effect of the direction on incoming wind at each distance from the shelterbelt.

Calculations

The coefficient of resistance ($k_r$) was calculated for each caragana shelterbelt by using a nonlinear regression. The formula developed by Wilson et al., 1990, was:

$$(U_{25}-U_{min})/U_{25} = k_r/(1+2k_r)^{0.8}) \quad [1]$$

where U25H is the unaffected U at 25H, $U_{min}$ is the minimum U behind the shelterbelt, and $k_r$ is the coefficient of resistance of the shelterbelt.

## RESULTS AND DISCUSSION

Windspeeds from July through September, averaged 2.7 m $s^{-1}$. These are described as medium wind velocities (Bean et al., 1975), therefore, no consideration was given to sheltering efficacy because of high or low U intensity. In this study, a significant reduction in U was observed for winds originating from ±56° off ⊥ to the shelterbelt at 3H and 5H. However, wind reduction recorded at 1H for winds from due N was significantly less than for ENE or WNW winds. The width of a shelterbelt increases its density, which in turn can increase the effectiveness of the shelterbelt in reducing U (Heisler and Dewalle, 1988). So, when significant reductions of U were recorded at 1H for winds originating from the ENE or WNW, it may have been because the wind flow had to pass through a greater width of the shelterbelt than if it were flowing straight through from the N. Moreover, as the angle of incoming wind becomes more oblique the effective distance to measurement increases (i.e. the hypotenuse at 1H for a wind coming in at 45° would be 1.4H).

The distance between 4H and 6H is usually the region where the lowest U is recorded (Heisler and Dewalle, 1988). The lowest RWS for

caragana field shelterbelts studied here occurred at downstream locations of about 3H-5H: a predictable result. Consistent with other research, the recovery of U to 90% of $U_\infty$ varied according to the direction of the incoming wind, such that the greatest protective range occurred when winds were coming downwind and $\perp$ to the belt (Bean et al., 1975; Rollin, 1983). Unpredictable, however, was the seemingly small effect of foliage on the length of the protected region. This result may be artificial, however, because recovery was forced at 25H. In other studies, the loss of foliage diminished the effectiveness of field shelterbelts some 50% and reduced the protected range in their lee 50-65% (Nord, 1991). The loss of foliage in this study did, however, diminish the efficiency of the shelterbelt (Fig. 2).

Coefficient of resistance (kr)

Promoters of field shelterbelts would like to have a term that describes the effectiveness of field shelterbelts. Porosity ($\emptyset$) ratio of open space over the entire surface area of the shelterbelt, is one such term, and it has been the primary means of characterizing a shelterbelt (Hagen and Skidmore, 1971). Porosity characterization is problematic, however, because natural barriers are complex and defy the photographic two-dimensional analysis often used. More thorough analyses of stand density by counting the number of stems of specified diameters does provide a replicable, though time-consuming, appraisal of porosity (Bean et al., 1975; Heisler and Dewalle, 1988). Other terms are the coefficient of resistance ($k_r$) and the relative wind reduction ($U_{min}/U_\infty$). In this study, a natural barrier was used and neither porosity nor a coefficient of resistance ($k_r$) of the belt were known. However, the minimum windspeed ($U_{min}$) behind the shelterbelt and the unaffected windspeeds ($U_\infty$) were known and by substituting them in formula [1], a value for $k_r$ was derived.

The use of $k_r$ is preferable because $k_r$ is directly derived from air flow characteristics. In contrast, air flow through two different belts may be different even if shelterbelt width and porosity are equal (Wilson et al., 1990, and Wilson, 1987).

The $k_r$ values for in-leaf caragana field shelterbelts ranged from 2.2-7.2, while the out-of-leaf value was 1.7. The photograph of each one of the sites, shows differences between the in-leaf and out-of-leaf field shelterbelts that produced the different coefficients of resistance. The variable resistivity of the in-leaf field shelterbelts is probably a function of growth vigor rather than planting density because the resistivity of the out-of-leaf field shelterbelts had little variability.

## CONCLUSION

Having fixed 25H as the undisturbed location, we conclude that in south-central Alberta the presence of caragana: (1) reduced winds originating N and perpendicular to the shelterbelt out as far as 15H. To a lesser extent winds were also reduced, but only as far as 3H, for winds originating from the southern, eastern and western quadrants; (2) in-leaf field shelterbelts reduced wind velocities more effectively than out-of-leaf field shelterbelts, but both reduce U;

and, (3) whether described by resistivity $k_r$ (1.7-5.8), or relative wind reduction $U_{min}/U_\infty$ (.23-.36), the different methods agreed with the relative effectiveness of the field shelterbelts to reduce wind.

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Figure 1. Visual comparision of in-leaf and out-of-leaf caragana shelterbelts.

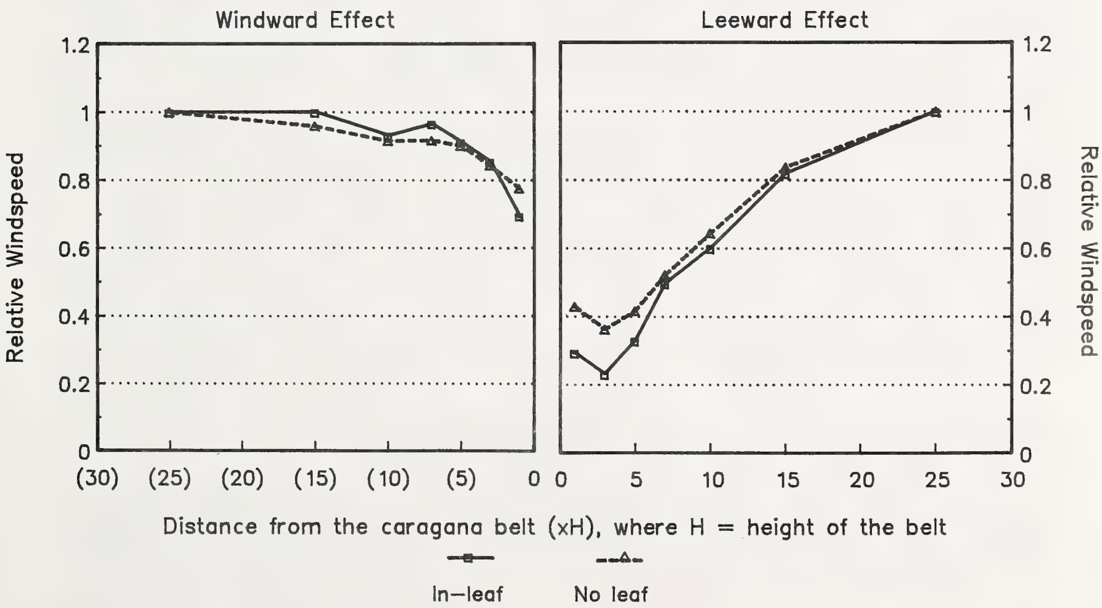


Figure 2. Relative windspeeds around Caragana arborescens shelterbelts. Winds measured included those perpendicular to the belt (±56°), both windward and leeward.

# THE EFFECTS OF FIELD SHELTERBELTS ON SOIL MOISTURE AND CROP YIELD IN ALBERTA, IN 1990 AND 1991

J. Timmermans, C. Sprout and I. Laslo[1]

## INTRODUCTION

Field shelterbelts are an important part of the soil conservation effort in Alberta. Shelterbelts provide numerous benefits such as reduced soil erosion by wind, increase in soil moisture by snow trapping, and reduced wind damage to crops.

Research conducted in Saskatchewan suggests that field shelterbelts increase the yield of spring wheat by an average 5 per cent. This is after taking into account the space occupied by the belt and adjacent zone of competition by the tree roots. To help promote planting of field shelterbelts by Alberta farmers, data taken under local conditions must show positive (or at least no negative) economic returns. This project was therefore initiated in 1990 and repeated in 1991, to quantify the effects of field shelterbelts on spring soil moisture and crop yields.

## METHODS

A total of 14 field shelterbelt sites were sampled in 1990 and 1991. These sites are located in Pincher Creek, Vulcan, Carmangay, Crossfield, Acme, Carbon, Consort, and Barrhead areas. The sites selected have mature shelterbelts with adjacent cropped fields. Five belts are orientated N-S and nine E-W. Three of the belts are mixed belts of deciduous tree and shrub varieties. The rest of the belts are single row caragana. Spring wheat was planted at 11 sites, barley at 6 sites and canola at one site.

At 9 field locations soil moisture samples to a 120 cm depth were taken in the spring just prior to seeding. The soil sampling sites were located in a line perpendicular to the belt on the leeward side. There were three lines or replicates at each field location spaced 10 m apart. There were eight or nine sampling sites on each line. Each sampling site was a distance from the center of the belt as follows: (h=height of the belt) 1/2h, 1h, 2h, 3h, 5h, 10h, 15h, 20h, and 30h. The 30h site was assumed to be beyond the range of influence of the shelterbelts, and therefore assumed to represent the open field moisture and yield levels.

The crop available moisture (mm to a depth of 120 cm) was determined for each soil sampling site. The percent of open field available moisture was also calculated to allow calculation of average values, treating the field locations as replicates.

At all 14 field locations 2 square meters of crop were taken at each of the distances from the belt that are described previously. Grain weights were measured for each site and absolute and relative grain yields were calculated.

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## RESULTS

The results from data collected in 1990 (figure 1.) show a yield curve with a decreased yields from 0h to 1.5h and increased yields from 1.5h to 20h with the largest increase at 5h. The relative yields are not significantly different except at 1/2h. The lack of significant difference is due to the high variability between field locations or replicates. The average yield in 1990 for the 0h to 20h area is 11% greater than the open field yield at 30h. The 1990 moisture curve shows that the shelterbelts trapped a significant amount of moisture in the 0h to 20h area with an average increase of 77% over the open field available moisture at 30h.

The 1991 data (figure 2.) show a very similar moisture curve to that from 1990, with an average increase of 81% in available moisture in the the 0h to 20h range. The 1991 yield curve however is quite different from 1990 with an average increase of only 4%. The difference in yield response between years is largely due to generally adequate rainfall in the growing season of 1991 and less than adequate rainfall in 1990 particularly at the Vulcan site. The moisture data at the Vulcan site were taken before any of the spring rain in 1991.

At the Vulcan site (figure 3.) in 1990 the average yield in the 0h to 20h area was 69 bu/ac, 72% higher than the open field yield of 40 bu/ac. The 1991 yield at the Vulcan site in the 0h to 20h area was 58 bu/ac, virtually the same as of 57 bu/ac. In a wet year it is expected there will be little difference in yields. The extra moisture trapped by the belt along with adequate growing season precipitation in 1991 may have been in excess of crop needs. Rainfall beginning in May largely equalized the available moisture, and reduced the moisture benefit from trapped snow.

The combined 1990 & 1991 data (figure 4.) show an average increase of 79% in available moisture and a 7% increase in yield in the 0h to 20h area over the open field area at 30h. These results are similar to those found in Saskatchewan. Since most of the crops in this project were wheat it is not unexpected to have a reasonable low increase in yield as wheat is somewhat drought tolerant.

A comparison of the effect of shelterbelt orientation on moisture and crop yield is shown in Figure 5. The east-west belts show an average 97% increase in available moisture and a 10% increase in crop yield in the 0h to 20h area. This compares to a 44% increase in available moisture and no increase in crop yield for the north-south belts. This may be because most winds which bring snow are from the north, and therefore result in more snow trapped on the south side of east-west belts.

## CONCLUSION

The results of this project indicate that field shelterbelts increase the available moisture reserve and yield within the leeward zone of its influence. The loss of yield in the 0h to 2h area is more than compensated for by the increase in yield in the 2h to 20h area. The largest beneficial effects on yields are realized in a dry year when growing season precipitation is most limiting to crop yield.

Thus far, our work has shown that east-west belts are more effective than north-south belts in trapping snow, increasing the available moisture reserve and crop yields. The north-south belts will provide more wind erosion protection to crops and soils, particularly in southern Alberta where the most erosive winds are from the west.

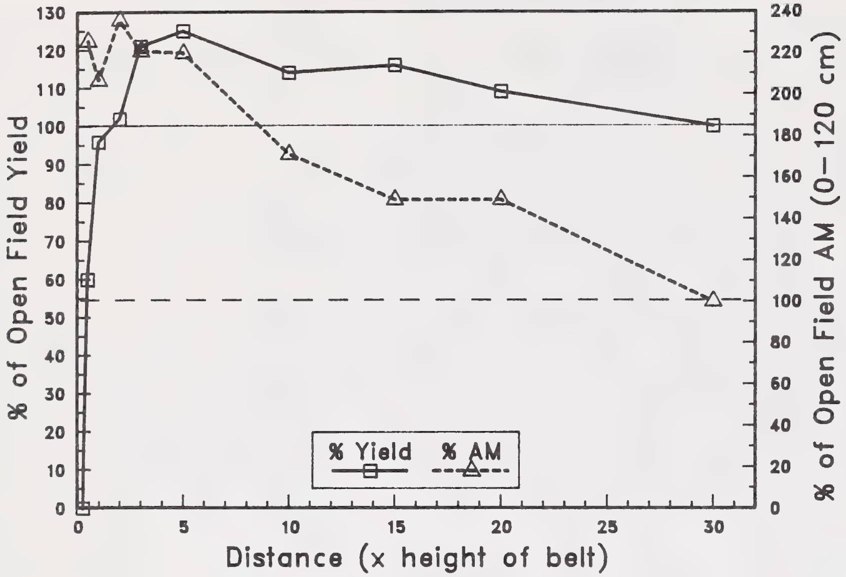


Figure 1. Shelterbelt effect on spring soil moisture and crop yield for 1990 data from six fields.

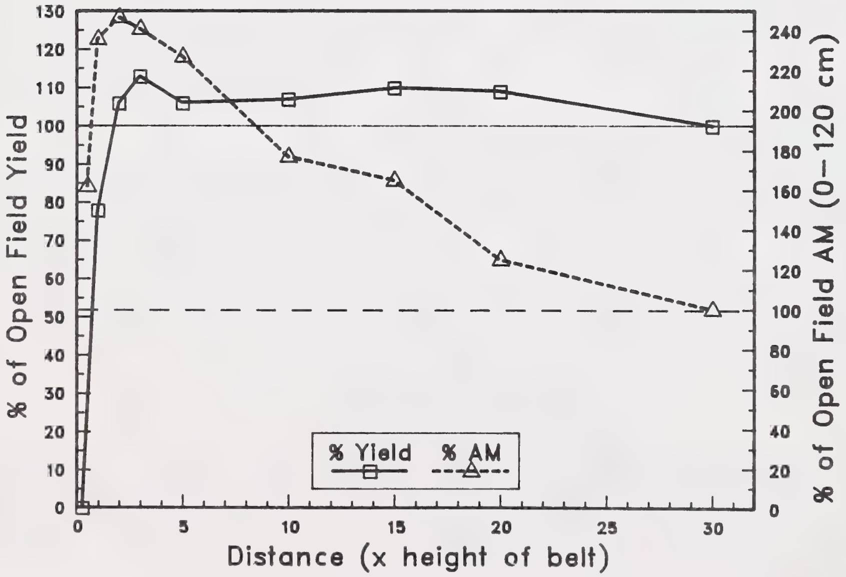


Figure 2. Shelterbelt effect on spring soil moisture and crop yield for 1991 data from eight fields.

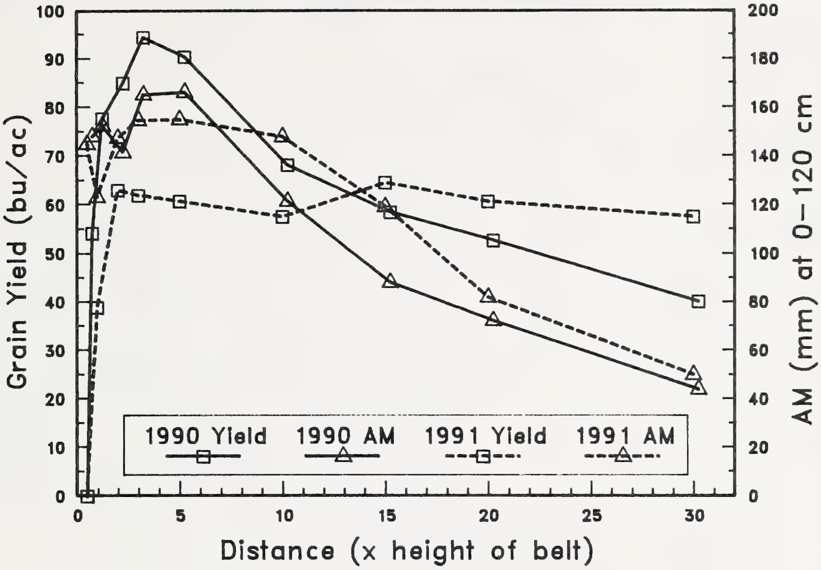


Figure 3. Shelterbelt effect on spring soil moisture and crop yield at the Vulcan site.

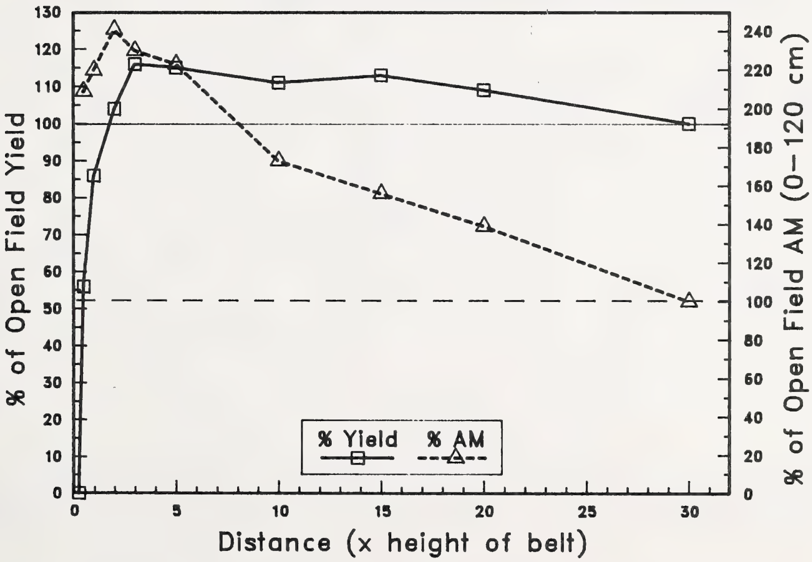


Figure 4. Shelterbelt effect on spring soil moisture and crop yield for combined 1990 & 1991 data.

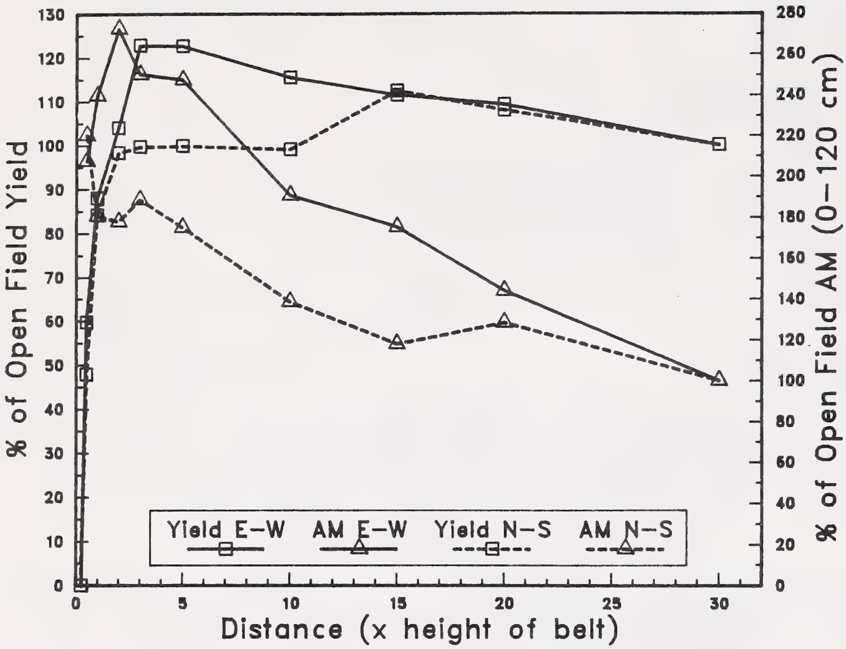


Figure 5. A comparison of the effects of shelterbelt orientation on spring soil moisture and crop yield for combined 1990 & 1991 data.

# AN EVALUATION OF SNOW TRAPPING BY FIELD SHELTERBELTS

J. Timmermans and C. Sprout[1]

## INTRODUCTION

Field shelterbelts provide many advantages for improving the growing environment of crops. One of the main advantages (although not unanimously agreed with by farmers), is the trapping of drifting snow. Trapped snow will increase spring soil moisture available to crops and hopefully increase yields. The amount, distribution and retention of is determined by the unpredictable nature of the weather, and also by the nature of the shelterbelt (height and porosity), and by its orientation. This project was carried out over the winter of 1990-91 to quantify snow accumulation, distribution and retention leeward of three caragana belts in south central Alberta.

## METHOD

Three field sites were monitored from November 2, 1990 to March 6, 1991 at weekly intervals. One site is east of Crossfield (Storch), another east of Acme (Boake), and the last north of Vulcan (Graham). All sites have mature single row caragana belts between four and five meters tall. The belts at Acme and Vulcan are orientated east-west and the belt at Crossfield is north-south. The Crossfield and Vulcan sites had standing stubble and the Acme site had been cultivated once over leaving a semi-buried flat residue cover.

Snow depth measurements were made along three transects spaced 50 meters apart and down wind of the belt at distances of 1, 2, 3, 5, 10, 15, 20, and 30 times the shelterbelt height (h). Stakes marked at one meter from the ground were placed at each distance to facilitate easy measurements of snow pack depth. A precipitation gauge was placed at each field at the 30h or open field location. The gauge proved to be unreliable in collecting the wind-driven snow and therefore an accurate measurement of the total precipitation was not obtained. Soil moisture samples were also taken in the fall of 1990 and the spring of 1991 in order to determine the contribution to the spring available moisture reserve by the snow trapping.

## RESULTS

Figure 1 shows the snow depth profiles as of March 6, 1991. This date was selected because it gave the best representation of the contribution to the spring soil moisture reserve. Snow melt before

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this date would have larger losses to evaporation and runoff rather than entering the soil. The two more northerly sites, Boake and Storch, received less snow over the study period than the Graham site in the south.

At 30h, or open field location, there was about twice as much snow at the Graham site as the other two sites. However at 3h there is almost seven times as much snow at Graham.

The north-south belt (Storch) did not show any appreciable trapping of snow. The east-west belts did show significant trapping in the 1h to 7h zone. These results are not unexpected as most snow is accompanied by northerly winds which cause drifting on the south side of a barrier. Dense caragana belts tend to trap snow in large drifts near the belt where the wind reduction is greatest.

The Boake site accumulated an average of three times and the Graham site five times as much snow in the 1h to 7h region as the open field. The Boake site may not have been as effective as the Graham site as there was flat stubble at Boake and a field to the north with a system of belts that probably trapped a lot of drifting snow. At Graham there was standing stubble and it is the northern most belt of a system of belts with no other barriers for miles to the north.

Figure 2 plots the variation in snow depth at the point of maximum accumulation at each site over the winter. The largest contribution to the snow pack occurred in the latter part of December and persisted until the first part of February. At this time there was a 45% loss of the snow pack at Graham, 79% at Boake, and 100% at Storch. The Graham site trapped more snow and retained more snow than the other sites and therefore contributed more to the spring soil moisture reserve. The soil moisture data in Table 1 supports this conclusion.

Table 1. Average available moisture (mm) in 0-120 cm depth.

| | Boake | | | Graham | | |
|---|---|---|---|---|---|---|
| Distance | Fall 90 | Spring 91 | Diff. | Fall 90 | Spring 91 | Diff. |
| 1h | 97.6 | 156.9 | 59.3 | 2.6 | 157.5 | 154.9 |
| 2h | 151.4 | 167.1 | 15.7 | 8.3 | 176.2 | 167.9 |
| 3h | 151.3 | 157.7 | 6.4 | 13.1 | 158.5 | 145.4 |
| 5h | 118.9 | 132.9 | 4.6 | 23.2 | 162.9 | 139.7 |
| 10h | 114.6 | 107.1 | 7.5 | 19.7 | 102.5 | 82.8 |
| 15h | 80.7 | 97.9 | 17.2 | 20.1 | 113.0 | 92.9 |
| 20h | 85.0 | 71.5 | -13.5 | 21.7 | 72.2 | 50.5 |
| 30h | 53.1 | 55.5 | 2.4 | 24.8 | 63.4 | 38.6 |

## CONCLUSION

The effectiveness of shelterbelts in trapping snow is dependent on a number of factors including shelterbelt orientation, residue cover, porosity of belt, and the presence other barriers windward of the belt. If the conditions are favorable, a shelterbelt can trap and retain significant amounts of snow over winter. The accumulated snow adds to the spring available moisture reserve and may contribute to improved crop yields, especially where growing season precipitation is limited.

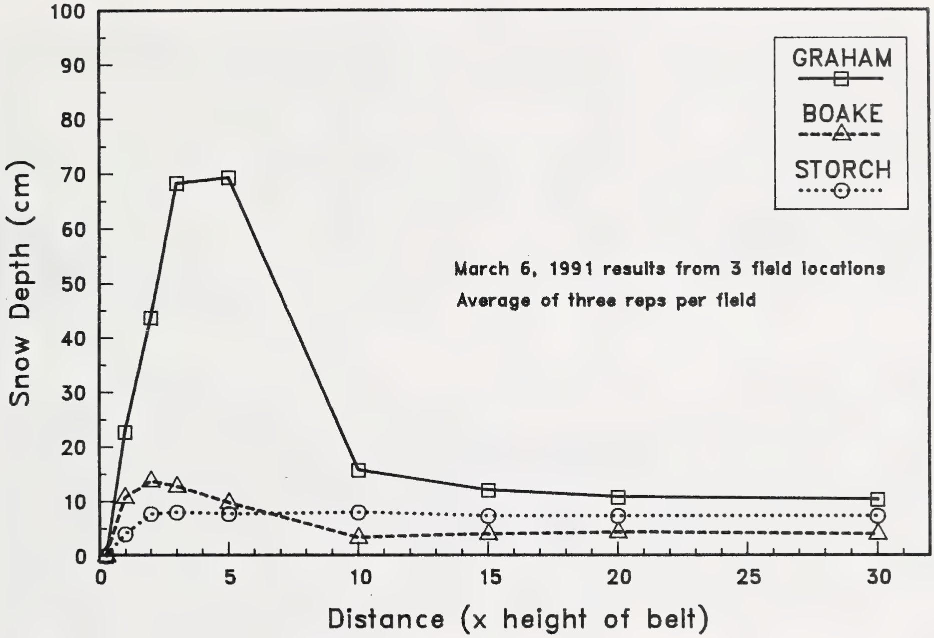


Figure 1. Shelterbelt effect on snow trapping.

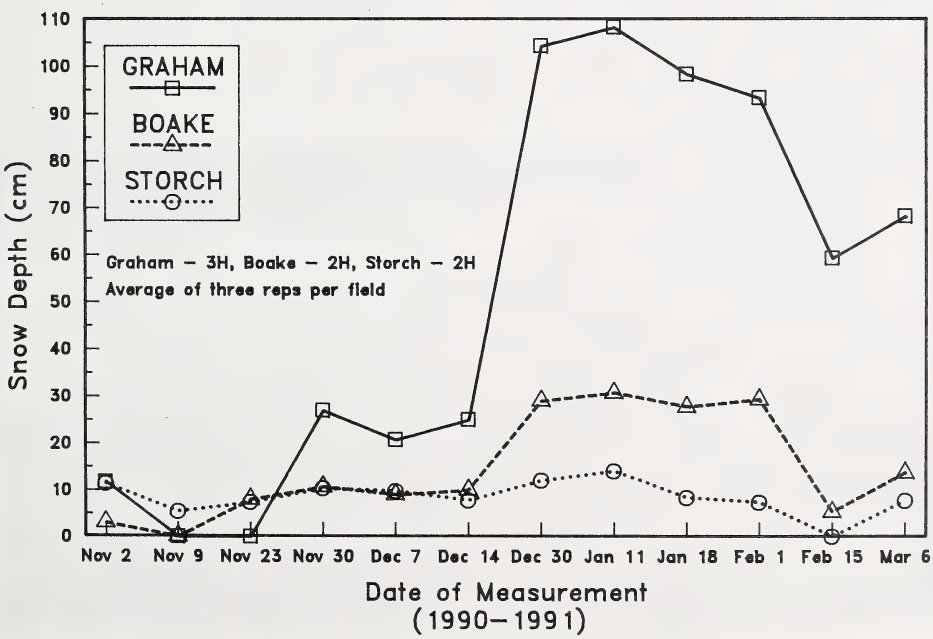


Figure 2. Maximum snow depth behind field shelterbelts.

Figures 1 and 2. Snow drifted on south side of caragana shelterbelt at Graham site near Vulcan, on March 15, 1991.

# COMPARISON OF SOLUBLE CALCIUM AND MAGNESIUM MEASUREMENTS BY EDTA TITRATION AND ICP EMISSION SPECTROMETRY

K. Au[1], G. Mankee[1] and G.B. Schaalje[2]

## INTRODUCTION

Determination of soluble calcium and magnesium concentration in soil extracts by titration with ethylenediaminetetraacetate EDTA (Heald 1965) has been the standard method for decades. Since the International Winter Conference of Developments in Atomic Plasma Spectrochemical Analysis in 1980, (Barnes 1981) the inductively coupled plasma (ICP) emission spectroscopy technique has been adopted rapidly by soil testing laboratories to replace and/or supplement the EDTA titration method. A direct cost benefit to testing laboratories may be realized in labour, sample-handling time and maximum utilization of the instrument because the ICP method is capable of determining a number of elements simultaneously using automated analyses (Jones 1980). Disadvantages of the ICP method include concerns related to the analytical stability of the instrument over a long period of time and the concentration levels of the soil extract are generally considerably above detection limits (Jones 1980). The purpose of this project was to compare the overall accuracy of the two methods (EDTA vs. ICP).

## MATERIALS AND METHODS

A total of 490 soil saturation paste extracts were prepared (U.S. Salinity Lab Staff 1954) by Norwest Laboratory in Lethbridge and the soluble calcium and magnesium concentration in each extract was determined using the EDTA titration method (Heald 1965) and an Applied Research Laboratories ICP instrument (Model ARL 34000) (Appendix).

The means and variances of measurement data were determined from the two methods. Sample measurements obtained from both EDTA and ICP methods were analysed statistically to obtain upper and lower acceptance limits for ICP measurements (Steel and Torrie 1960; Au et al. 1991). Scattergrams of soluble calcium and magnesium concentration were plotted using EDTA titration on the x-axis and the ICP data on the y-axis. Correlation coefficients were computed and 95% acceptance limits were calculated.

In addition to the analyses performed by Norwest Laboratory, 47 of the samples used for the preceeding assessment (proficiency samples) were randomly selected and analyzed using the EDTA method in the Soil and Water Laboratory, Alberta Agriculture. These data were plotted on the x-axis against EDTA and ICP data from Norwest Laboratory on the y-axis. Upper and lower acceptance limits, as stated in Alberta Agriculture service agreements for standard soil chemical analysis, were also plotted.

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## RESULTS AND DISCUSSION

The means and variances of soluble calcium and magnesium concentration, as determined by EDTA and ICP methods, and the correlation coefficient and error-mean-square between EDTA and ICP measurements are presented in Table 1.

Table 1. Mean values of analyses results from EDTA titration method and ICP method and the analyses of variance

| Parameter | Range | EDTA Data Mean | EDTA Data Variance | ICP DATA Mean | ICP DATA Variance | Correlation Coefficient | Error Mean Square Between Methods |
|---|---|---|---|---|---|---|---|
| Ca & Mg | 1.0-180.0 meq/L | 30.50 | 1271.50 | 30.30 | 1217.40 | 1.00 | 0.0009* |
| | 1.0-11.0 meq/L | 5.40 | 5.40 | 5.60 | 5.90 | 0.99 | 0.0661 |
| | >11.0-180 meq/L | 57.40 | 1231.00 | 57.00 | 1149.50 | 1.00 | 0.0006* |

*Based on a logarithmic transformation of the data.

The relationship between EDTA and ICP data from Norwest Laboratory (Fig. 1) is similar to the relationship between EDTA data from private laboratories and EDTA data from the Soil and Water Laboratory, Alberta Agriculture (Au et al. 1991), with the Norwest data having a much smaller error-mean-square value and narrower acceptance limits (Table 2). Soluble calcium and magnesium concentration determinations using the EDTA and ICP methods in the Norwest Laboratory thus had smaller error than analyses conducted using the EDTA method in two different laboratories. Furthermore, the measurement of proficiency samples using EDTA and ICP data from Norwest Laboratory compared well with EDTA measurements from the Soil and Water Laboratory, Alberta Agriculture, with data being within the established upper and lower limits 95% of the time (Fig. 2).

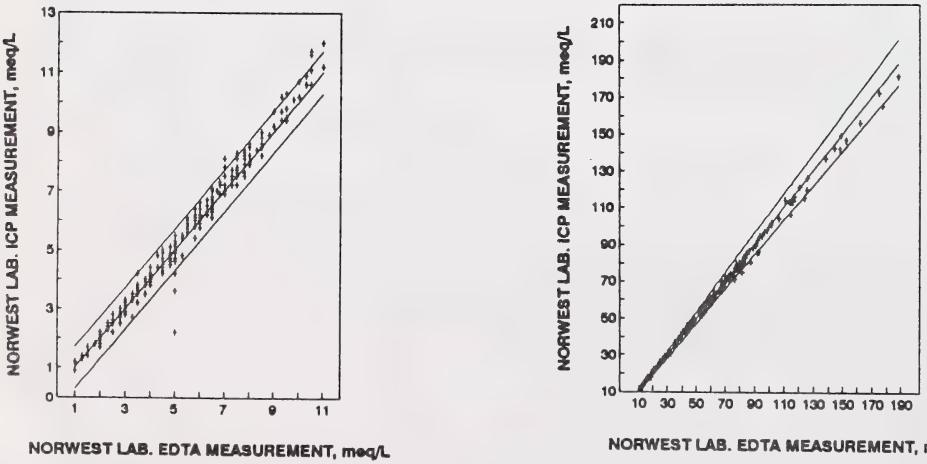


Figure 1. Additive (fixed amount differences) and mutiplicative (fixed percentage differences) relationships between EDTA and ICP measurements by Norwest Laboratory.

Table 2. Upper and lower acceptance limits of Ca & Mg obtained by ICP, computed from analysis results of 490 soil samples.

| Parameter | Range | Upper Limits | Lower Limits |
|---|---|---|---|
| Ca & Mg | 1.0-180.0 meq/L | | |
| | 1.0-11.0 meq/L | control value + .71 | control value - .71 |
| | >11.0-180 meq/L | control value x 1.07 | control value / 1.07 |

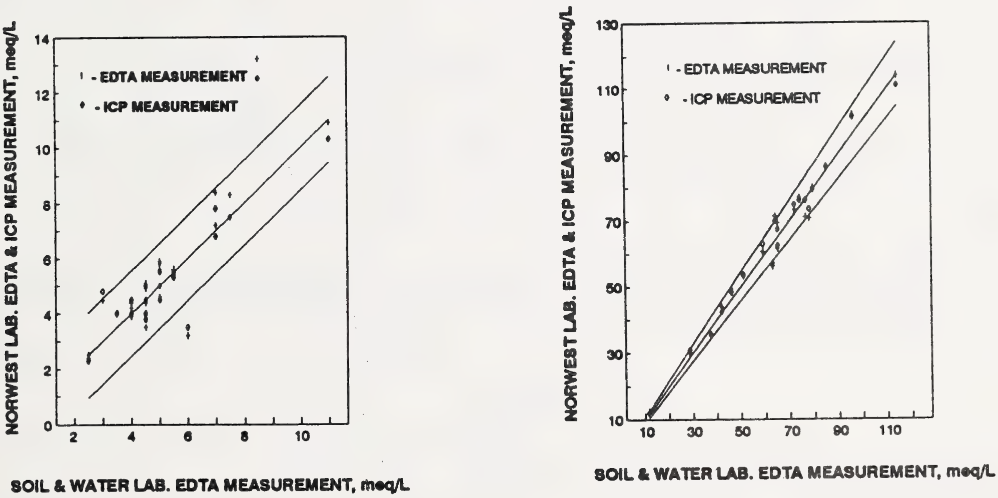


Figure 2. Proficiency sample measurements by Norwest Laboratory and the Soil and Water Laboratory, Alberta Agriculture.

## RECOMMENDATIONS

From the results of this study, it is recommended that the ICP method may be utilized to replace and/or supplement the EDTA titration method for determination of the soluble calcium and magnesium concentration in soil extracts. It is also recommended that the upper and lower acceptance limits stated in current service agreements for standard soil chemical analysis be implemented as the accepted limits for soluble calcium and magnesium analyses by the ICP method. Sample preparation, operating conditions, instrument calibration, analysis of samples, instrumental quality control, method quality control, and tests for matric interference are of the utmost importance in producing accurate and reliable analyses using the ICP method (Clesceri et al. 1989).

## ACKNOWLEDGEMENTS

The authors thank K. Mrazek and D. Kinsey from Norwest Laboratory, Lethbridge, for providing the soil extract data, D. Mikalson for statistical analyses, A. Able and L. Ontkean for typing, and R. Bennett for reviewing this report.

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## APPENDIX

Argon ICP Source Condition and Operating Parameters for the ARL 34000 for Determining Soluble Calcium and Magnesium Concentration by Norwest Laboratory in Lethbridge.

R.F. Generator:

Incident Power - 1150 Watts

Excitation:

| | |
|---|---|
| Plasma Gas (Argon) Flow (L/min) | 0.8 |
| Carrier Gas Glow (L/min) | 1.0 |
| Liquid Uptake Rate (mL/min) | 2.9 |

Readout:

| | |
|---|---|
| Pre-integration time (sec) | 50 |
| Integration time (sec) | 10 x 3 |

Spectrometer:

| | |
|---|---|
| Grating (Lines/mm) | 1080 |
| Primary Slit Size (Microns) | 20 |
| Vacuum (Microns) | 25.0 |

Nebulizer:

Meinhard Type C

| Element | Wavelength | Detection limit | Inter-element correction |
|---|---|---|---|
| Ca | 317.9 nm | 0.00181 ppm | NIL* |
| Mg | 279.1 nm | 0.01771 ppm | NIL* |

*Refer to operating manual.

# EVALUATION OF WATER EVAPORATION RATES FROM ONE LITRE METAL MOTOR OIL CANS, WITH AND WITHOUT DIESEL FUEL AS A SUPPRESSOR

T. O'Reilly and L. Morrison[1]

## INTRODUCTION

In the spring of 1991, the Medicine Hat Irrigation Branch office undertook an adaptive research project to evaluate the application efficiencies of linear sprinkler systems under southern Alberta's climatic conditions. This study was highly dependant upon obtaining an accurate recording of the amounts of water caught in catch containers. It was recognized that the linear irrigation system would be passing through the fixed test site at various times of the day. This did not always coincide with times during which manpower was available and hence, inaccuracy resulting from evaporation was a concern. The need was identified to determine what an acceptable time lag would be in recording measurements from the catch containers, with and without the use of a evaporation suppressor.

The intent of this evaluation was: to determine the effectiveness of diesel fuel as an evaporation suppressor in one litre, metal collectors and; to establish the maximum time interval allowed between irrigating and recording catch can measurements such that test results are not significantly distorted by evaporation.

## METHODS

One litre, metal motor oil cans are considered to be a favorable selection for collector containers (Marek et al., 1960). These cans are readily available and have relatively good data collection characteristics including a sharp entrance edge and sufficient depth to prevent water from splashing out. In addition, they offer some wind and shade protection. Poor characteristics associated with these cans is their tendency to rust and ability to absorb incoming solar radiation and conduct heat, thereby potentially increasing the evaporation of water from within the can as well as from water droplets clinging to the sides (Heermann, 1980).

Prior to conducting this study, the workability of various evaporation suppressors was examined. Oils were found to be messy to work with and difficult to extract form the containers. The inside walls of the cans were spray painted to improve the ease with which oil was poured out but the paint eventually peeled, thus affecting subsequent readings. Diesel fuel was selected as the test evaporation suppressor as it proved to have more favorable handling characteristics than did oils.

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[1] Irrigation Branch, Irrigation and Resource Management Division, Alberta Agriculture, 1015-30 Street S.W., Medicine Hat, Alberta, T1B 3N3.

The test site was located in a chain-linked fenced compound behind the Medicine Hat district office building. The compound's ground surface is gravelled with no vegetation present. Where applicable, tests followed guidelines set by ASAE (Hahn and Rosentreter, 1987). For the test, four cans were installed in a one metre square pattern. All cans were clean and free of rust with no visible deformities. Each can was individually attached in a vertical position to a 1.2-metre lath stake using large rubber bands. Two of the cans contained water only and the other two cans contained water and diesel fuel.

At the beginning of each test period, the four cans were filled with 203 mls of water using a plastic graduated cylinder. The amount of water selected for this test is equivalent to a 25 mm net irrigation. Two of the cans then had 27 ml of diesel fuel added to them. The amount of diesel fuel added was determined as being of sufficient quantity to cover the surface area of the can with a thin film layer.

Measurements were taken from each of the four cans at one to two hour intervals between the hours of 0815 and 1630. Measurements were obtained by emptying the contents of each can into a plastic graduated cylinder. The same plastic cylinder was used for all measurements. Readings were recorded by volume and converted to depth by dividing by the can surface area. Taking depth readings directly from the cans using a ruler was not considered to be sufficiently accurate since the bottom of the cans was slightly convex and the manufacturing tolerances of the can were questionable.

A total of 17 measurements were taken on each of the four cans. At each recording, the time and weather conditions were noted. Evaporation readings were combined and averaged as there was insufficient duplication of tests performed under the different weather conditions. Results were grouped according to time of day.

## RESULTS AND DISCUSSION

Individual can evaporation rates ranged from 0.02 to 0.69 mm/hr for cans with water plus diesel fuel and from 0.06 to 1.18 mm/hr for cans with water only (Table 1). Time of day appeared to substantially affect average evaporation rate (Figure 1). There were no measurable differences in evaporation rate for readings taken between 0830 h and 1200 h. Conversely, the highest evaporation occurred during the afternoon with rates of 0.24 and 0.47 mm/hr, with and without diesel fuel, respectively. The greatest percent difference in evaporation rate occurred overnight as measurements from collectors with diesel fuel were 4.5 times that recorded from cans without diesel fuel. Considerable differences in night-time evaporation rate could be due, in part, to the diesel fuel trapping dew or moisture from the air.

**Table 1:** Evaporation Rate From One Litre, Metal Oil Cans.

| Date (YMD) | Time (24hr) | Temp (°C) | Wind (KMPH) | Cloud | Evaporation rate (mm/h) Water only Can#1 | Can#2 | Water+diesel Can#3 | Can#4 |
|---|---|---|---|---|---|---|---|---|
| 910725 | 1330 | 33 | 7-15 | none | cans filled | | | |
| 910725 | 1430 | 34 | 7-10 | scattered | 1.125 | 1.25 | 0.875 | 0.50 |
| 910725 | 1530 | 33 | 5-7 | scattered | 0.50 | 0.62 | 0.375 | 0.25 |
| 910725 | 1630 | 34 | 5-7 | scattered | 0.50 | 0.87 | 0.375 | 0.25 |
| 910820 | 1630 | 27 | 2-4 | none | cans refilled | | | |
| 910821 | 0815 | 15 | 2-3 | none | 0.28 | 0.30 | 0.08 | 0.06 |
| 910821 | 1600 | 29 | 0 | none | cans refilled | | | |
| 910822 | 0830 | 16 | 5-8 | cloudy | 0.36 | 0.37 | 0.068 | 0.061 |
| 910903 | 1600 | 24 | 15-20 | none | cans refilled | | | |
| 910904 | 0815 | 5 | 2-5 | none | 0.28 | 0.28 | 0.05 | 0.06 |
| 910904 | 1600 | 22 | 2-8 | none | cans refilled | | | |
| 910905 | 0830 | 10 | 2-5 | none | 0.36 | 0.41 | 0.06 | 0.05 |
| 910905 | 1030 | 19 | 0-2 | none | cans refilled | | | |
| 910905 | 1345 | 20 | 0-4 | none | 0.27 | 0.42 | 0.15 | 0.15 |
| 910905 | 1545 | 21 | 2-10 | none | 0.28 | 0.25 | 0.25 | 0.19 |
| 910906 | 0830 | 9 | 0-4 | none | 0.015 | 0.004 | 0.015 | 0.022 |
| 910906 | 1030 | 19 | 0-4 | none | 0.06 | 0.06 | 0.125 | 0.062 |
| 910906 | 1330 | 28 | 0 | none | 0.13 | 0.125 | 0.125 | 0.042 |
| 910906 | 1530 | 29 | 2-6 | none | 0.13 | 0.25 | 0.06 | 0.187 |
| 910909 | 0900 | 9 | 5-8 | cloudy | cans refilled | | | |
| 910909 | 1100 | 12 | 0-3 | scattered | 0.19 | 0.19 | 0.125 | 0.19 |
| 910909 | 1330 | 15 | 0-3 | none | 0.30 | 0.30 | 0.25 | 0.20 |
| 910909 | 1530 | 16 | 0-2 | none | 0.50 | 0.50 | 0.0 | 0.125 |
| 910910 | 0830 | 10 | 0-2 | cloudy | 0.09 | 0.09 | 0.007 | 0.03 |

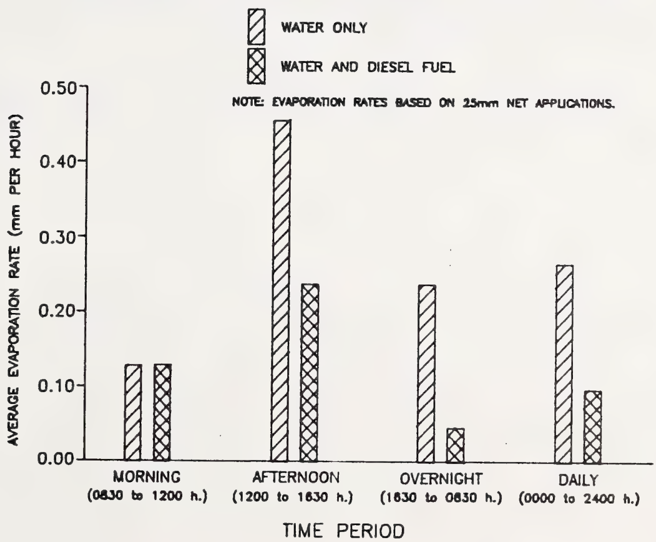


**Figure 1:** Average differences in evaporation between catch cans with and without diesel fuel as a suppressor.

## SUMMARY AND CONCLUSIONS

Diesel fuel proved to be an effective agent in reducing evaporative losses from one litre, metal collection cans. For purposes of sprinkler testing, it is recommended that cans be kept clean and free of rust and that measurements be recorded as soon as possible after an irrigation event in order to minimize evaporative losses which could potentially affect results. Adding diesel fuel as an evaporation suppressor would likely be most useful in sprinkler tests with low application rates where small amounts of evaporation from test cans would represent a proportionally greater error than tests with high application rates. It may also be advantageous to add diesel fuel if catch results cannot be measured directly after sprinkler testing.

Knowing the evaporation rate from test containers would allow researchers to adjust readings in the event that cans cannot be checked immediately following irrigation or if there is a significant time lag between measuring the amount of water collected in the first and last can. It may be advisable to install a check can containing a known volume of water adjacent to the test site. Check can evaporation could be quantified for the time interval between irrigation and recording catch can measurements. This value could then be used to adjust test data.

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# A COMPARISON OF SOIL MOISTURE AS DETERMINED BY THE NEUTRON SCATTER TECHNIQUE IN AUGERED VERSUS CORED HOLES

B. Read, V. Sawchuk and D. Wentz[1]

## INTRODUCTION

The neutron scatter technique is perhaps the most rapid and reproducible method of determining soil moisture content at depth. The method of installing access tubing in the ground to allow for this technique, however, is subject to some concern. A study was conducted to see if differences exist in soil moisture readings as determined by the neutron scatter technique in augered versus cored holes.

## METHODS

The neutron scatter technique of soil moisture determination involves the lowering of an encased radioactive source into the ground via an access tube (most commonly aluminum) to a desired depth. High energy or fast neutrons are emitted from the source into the surrounding soil. When the fast neutrons collide with atoms of similar mass, such as hydrogen, they lose energy. After about 20 collisions, the energy falls below a threshold level and the neutron is referred to as thermalized neutron. A dector in the source is responsive to the presence of thermalized neutrons, but is not responsive to high energy, fast neutrons.

In most soils, the major source of hydrogen is water. The presence of increasing amounts of soil water slows down the neutrons sooner, increasing the probability of a detector collision over that which would occur in dry conditions. The resultant signals are displayed electronically as an index of soil moisture.

When source rod conduit or access tubing is installed in the ground, every effort is made to ensure integrity between the soil and the outside wall of the tubing. This is done so that the passage of neutrons across this region is not influenced by unnatural voids, water pockets or disruptions in the soil. For this to occur, holes are cored into the ground at the same diameter as that of the access tube. The tube is then forced into the ground providing a tight fit.

It is often difficult, labor intensive and time consuming to core a hole to an exacting size due to soil moisture and textural conditions. As a result, holes are often augered instead, at a diameter as close as possible to that of the tube. The tube is then inserted and the soil is back-filled around the tube, either dry (most commonly) or as a slurry. The primary concern with the augering method is that unnatural voids may occur between the soil wall and the tube, especially at deeper depths where the back-fill may not adequately reach. Furthermore, the density and moisture content of the back-fill will not be the same as the original material and this may also cause a reading error.

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[1] Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, Agriculture Centre, Lethbridge, Alberta, T1J 4C7.

At a research site in the Crossfield, Alberta area, access tubes were installed in cored holes adjacent to existing augered-in tubes at four different sites, representing four different moisture conditions. All tubes were read on the same day with a Troxler 3222 soil moisture gauge, approximately bi-weekly from May 1990 to February 1991. One hundred and forty-four pairs of soil moisture readings were collected, thirty-six each from 30, 60, 90 and 120 cm depths. Data were grouped according to depth and regression analysis was performed to determine the correlation between the two variables. Differences in soil moisture between the installation methods was also calculated.

## RESULTS

Figures 1-5 present the graphic relationship between soil moisture at depth as read from augered and cored holes. In each case, the linear function has been plotted. The $r^2$ values for each comparison range from $0.89$ at the 30 cm depth, to $r^2$=0.78 at 60 cm, $r^2$=0.79 at 90 cm and $r^2$=0.74 at the 120 cm depth. When the data were grouped as a whole, the resulting $r^2$ value was 0.63.

As a general trend, as soil depth becomes deeper, the correlation between the two variables also decreases. Even at the deepest increment though, the $r^2$ value is still good.

At the 30 cm depth, soil moisture measured from cored tubes exceeded that measured from augered 74% of the time. The average cored reading was 38.6% and the average augered reading was 36.9% (in all cases, moisture is read on a volume percent basis).

At the 60, 90 and 120 cm depths, the reverse was true. At these three depths, soil moisture measured from augered tubes exceeded that measured from cored tubes 64%, 61% and 53% of the time respectively. At 60 cm, augered tube moisture percent averaged 37.9 while cored tube mean moisture was 35.4%. Similarily at 90 cm, augered tube moisture exceeded cored tube moisture 37.7% to 34.6% respectively. At the 120 cm depth, mean soil moisture measured from augered tubes was 39.6% while average cored tube moisture was 35.3%. Differences in soil moisture (vol. pct.) between the installation methods according to depth are: 30cm, 1.7; 60cm, 2.5; 90 cm, 3.1; 120 cm, 4.3.

## SUMMARY AND CONCLUSIONS

The high correlation between soil moisture when read from cored versus augered tubes indicates that a strong relationship is present and that generally, moisture readings are similar when read from tubes installed by either method. This is further substantiated by the small difference in actual soil moisture readings between the two methods.

The highest correlation occurred at the most shallow depth (30 cm) where back-filling and tamping around the augered tubes was the most accessible and hence, the easiest to replicate the conditions which existed around the cored tubes.

It appears that while differences in soil moisture values occur between augered and cored tubes, the differences are small enough to be acceptable, especially when considering the often larger sampling errors which are present if the gravimetric method for example was used. It

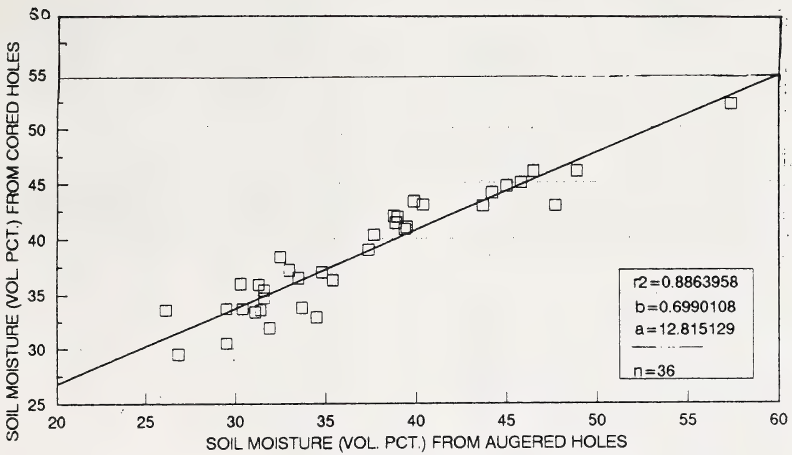


Figure 1. Comparison of soil moisture as determined from augered and cored tubes at the 30 cm depth.

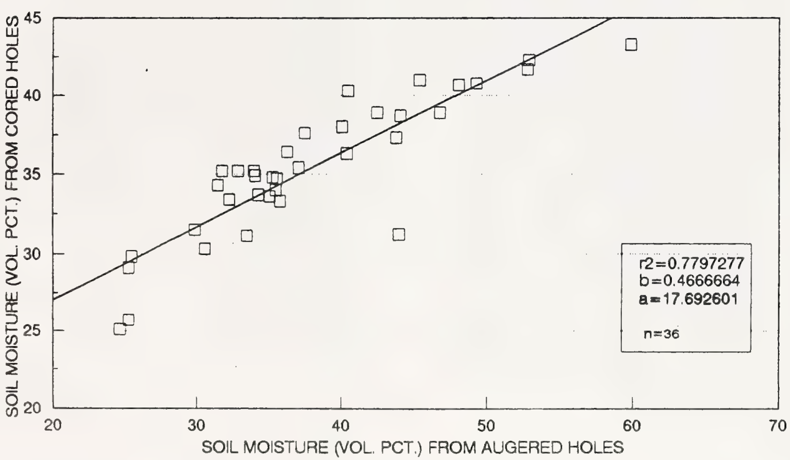


Figure 2. Comparison of soil moisture as determined from augered and cored tubes at the 60 cm depth.

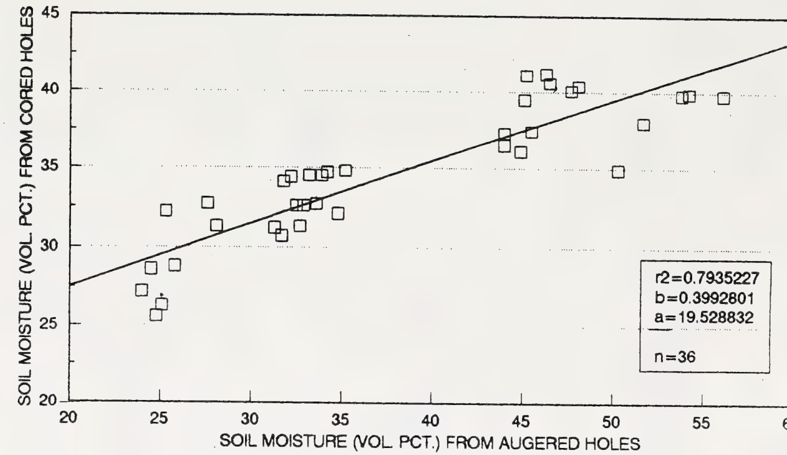


Figure 3. Comparison of soil moisture as determined from augered and cored tubes at the 90 cm depth.

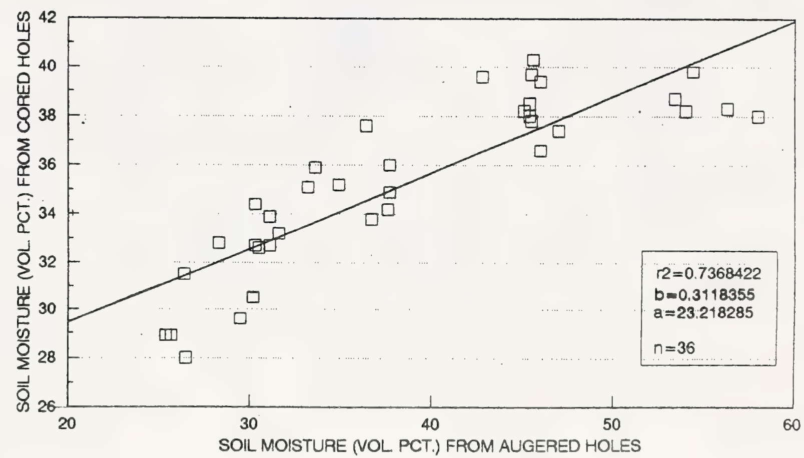


Figure 4. Comparison of soil moisture as determined from augered and cored tubes at the 120 cm depth.

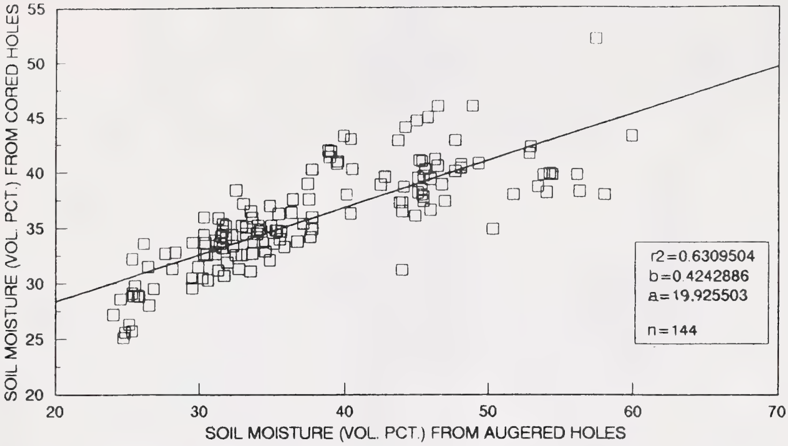


Figure 5. Comparison of soil moisture as determined from augered and cored tubes at 0 - 120 cm depth.

should be noted that the differences in moisture readings between tubes may be partly due to actual differences in soil moisture as much as errors due to inconsistencies in tube installation.

Over time, and with each successive wetting pattern, soil settling should occur, voids should be reduced and soil around the tubes should begin to approach field density. This would serve to reduce differences between the two methods.

The time and labor saved by augering as opposed to coring far outweighs any minor differences in soil moisture which may result from discrepancies in the augering method. Therefore, if care is taken in back-filling, augering is equally recommended as a method for the routine installation of neutron probe access tubes.

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# THE MEASUREMENT OF GROUNDWATER DEPTH USING THE EM31 ELECTROMAGNETIC CONDUCTIVITY METER

B. Read and D. Wentz[1]

## INTRODUCTION

The use of electromagnetic conductivity meters (Geonics EM31 and EM38) to determine apparent conductivity in soil salinity investigations is becoming widely accepted. Recent innovations in the application of the EM38 (Livergood, Read and Wentz, 1991) have contributed to the interest in the use of these instruments.

The EM38 is a tool specifically designed for soil salinity investigations and is most sensitive to conditions affecting conductivity in the top two metres of the soil. The EM31, on the other hand, was initially designed for shallow geophysical exploration and it is generally responsive, by design, to conditions within the top six metres of the soil profile. Shallow groundwater, which is often responsible for the upward movement of soluble salts and the formation of soil salinity, is usually found within this six metre zone.

A project was undertaken to determine if the EM31 was capable of accurately detecting shallow groundwater under a variety of field conditions.

## METHODS

Data were gathered at soil salinity investigation sites which contained a water table well from previous test drilling. The sites were located throughout southern Alberta primarily in the Milk River, Foremost, Acadia Valley, Hanna and Arrowood areas. A total of 33 sites were initially visited, but this number declined to 29 as four sites were disrupted by farming activities.

Data collection at each site consisted of reading soil conductivity with the EM31 meter in the vertical mode in conjuction with the measurement of the groundwater depth in each well. Data collection took place on a monthly basis from July through October, 1988 and from May through September, 1989.

## RESULTS

EM31a readings (x axis) were plotted against the depth to a water table (y axis) with data grouped into one metre depth increments. Correlation coefficients calculated for each individual depth from zero to five metres generally resulted in very low $r^2$ values indicating the absence of any significant relationships. In each case plotted best fit curves showed similar

[1] Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, Agriculture Centre, Lethbridge, Alberta, T1J 4C7.

trends even though the relationships were poor; that is, as water tables become deeper, the EM31 values decrease. When data were grouped as a whole, (n=217), the resulting $r^2$ was 0.44. Figure 1 presents the point scatter and the best fit curve (exponential function).

From the curve it is possible to roughly predict the depth to groundwater from EM31 readings. The accuracy of the prediction varies with depth, however. In the surface soils, that is 0.00 - 0.99 metres, there was no EM31 - water table depth relationship. The relative insensitivity of the EM31 at this depth was not unexpected though, since surface response in the vertical mode at the surface is generally considered zero (Wood). In the next deeper increment, the correlation coefficient improved to 0.19, generally remaining at this level from one to five metres. In the five to six metre depth, the relationship improved, with an $r^2$ of 0.46.

## SUMMARY AND CONCLUSIONS

Because the EM31's sphere of operation is so large, its readings are subject to the presence of and the variation in a number of factors such as shallow bedrock, soil moisture, temperature and texture. The development of the EM31 vs GW Depth curve does not take into consideration the effect which these variables may have on EM readings. To consider these factors on a site specific basis would require time consuming sampling to six metres in every instance and this defeats the purpose of rapid groundwater depth measurement.

The curve does allow for the prediction of groundwater depth, but only in a very general sense. In groundwater investigations, the EM31 may be of most value in determining if in fact groundwater is present within six metres rather than attempting to use the instrument to pinpoint exact groundwater levels.

In salinity investigations, drilling is required to install watertable wells for monitoring groundwater movement. Drilling is expensive and the proper selection of well sites is critical to minimize unnecessary drilling. The use of the EM31 to accurately locate shallow groundwater may expedite the selection of well sites and ultimately reduce salinity investigation costs.

With increased use it is becoming evident to the investigators that the EM31 is more of an interpretive tool than a definitive instrument, such as the EM38. The use of the '31 requires considerable experience to recognize the factors which influence EM readings and further experience to interpret the results.

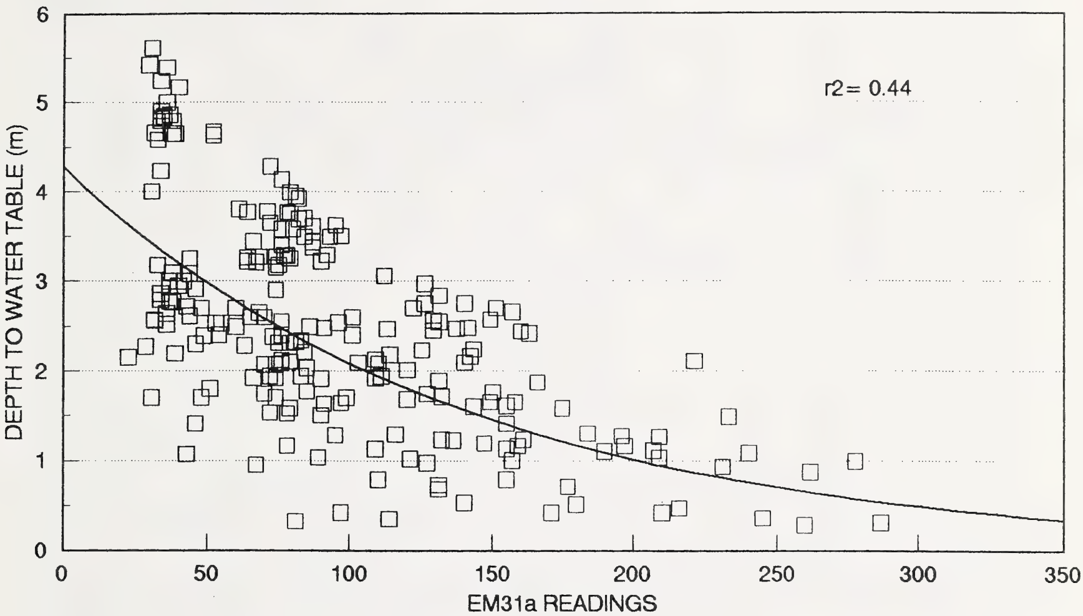


Figure 1. EM31 readings versus depth to groundwater.

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# DIRECT MOISTURE STRESS MEASUREMENT ON ALFALFA PLANTS GROWN FOR SEED

G. Snaith and D. McKenzie[1]

## INTRODUCTION

Growing alfalfa for seed has been largely a hit-and-miss affair, with much fluctuation in yield from one year to the next. These variations are mainly due to weather, specifically temperature and rainfall.

The Irrigated Alfalfa Seed Producers Association of Alberta has determined that its members have benefitted from growing alfalfa under contracts, which are often accompanied by a guaranteed floor price. These types of contracts are granted more readily by the seed companies if they can estimate fairly accurately how many acres to contract in order to obtain the desired quantity of seed.

It is generally accepted that irrigation is the largest contributing factor in determining yield, both positively and negatively. Moisture stress, required to obtain top yields, is presently measured by monitoring soil moisture. Measuring the desired amount of stress directly on the plant would enable a grower to more closely monitor plant condition and subsequently, make an appropriate decision regarding the amount and timing of irrigation.

The intent of this project was to determine if alfalfa growth characteristics exist which accurately indicate the plant's moisture stress level and which can be easily measured by a trained individual. Furthermore, these measurements need to be immediate enough that the grower can utilize them to irrigate in time to maintain flower production.

## METHODS

Individual stems were flagged (three to a site) and monitored at weekly intervals by a technician hired for this purpose through a Farming for the Future On-Farm Demonstration project. Sites were chosen at 20 farms in the area, and at the Alberta Special Crops and Horticultural Research Center (ASCHRC). Measurements were taken of five growth indicators which had potential for demonstrating a correlation with moisture stress. These included: the number of unopened buds, the number of racemes with at least one open floret, the main stem internode length, peduncle length from main stem to first floret and the tripping percentage. Soil moisture was monitored at all sites.

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[1] Irrigation Branch, Irrigation and Resource Management Division, Alberta Agriculture, Provincial Building, Brooks, Alberta, T0J 0J0.

## RESULTS AND DISCUSSION

### Unopened Buds Visible

The number of unopened buds at the top of the main stem were counted and recorded each week. At the start of flowering, there were between four and seven unopened buds. This number dropped steadily throughout the flowering period, but seemed to remain at one unless the plant became so dry that it could no longer support flowers. Although no actual size measurements were obtained, it was observed that the buds became smaller towards the end of the flowering stage. It is suspected that this signalled either a natural end to the flowering process (the yield potential had been reached) or an unnatural one (insufficient moisture). Therefore, we were reluctant to use this parameter to predict an irrigation.

### Racemes With at Least One Floret Open

This information was collected to determine the flowering pattern for alfalfa seed. It was desired that the grower have some idea as to how long each raceme stayed open and how often a new raceme was produced. It was discovered that racemes can be viable for five to 15 days, although we were not able to isolate the conditions which govern this variation. A new raceme was produced every three days, on average. Plants exhibited one to seven racemes open at any time. Most had either four or five racemes open simultaneously at the height of raceme production.

The most useful information garnered from this part of the project was that the plant tended to continue producing racemes as long as there was little pollinating taking place. The farm plots produced approximately 12-15 racemes while the ASCHRC plots, which were understocked with bees, had up to 29 racemes. Growers using leafcutter bees to pollinate their alfalfa crop must coordinate the 21 day incubation period required for pupae to hatch with first flower production. Bee incubation is usually delayed in years when cool weather may threaten their survival. Results from this study indicate that growers may not have to be so concerned that postponing bee incubation in cool years will affect seed production as plants appear to continue producing flowers until their yield potential is met.

### Main Stem Internode Length

Main stem internode length was measured to obtain the rate of main stem growth during flowering. While the rate of growth does slow as moisture stress increases, it does so at an irregular rate. For this reason, we decided not to use this measurement to predict timing of irrigation.

### Peduncle Length From Main Stem to First Floret

Peduncle length was measured after the first floret on the raceme was open as growth ceases once this stage has been reached. Initially, peduncle length was thought to be dependent on soil moisture but this relationship was not demonstrated on the ASCHRC plots (figure 1).

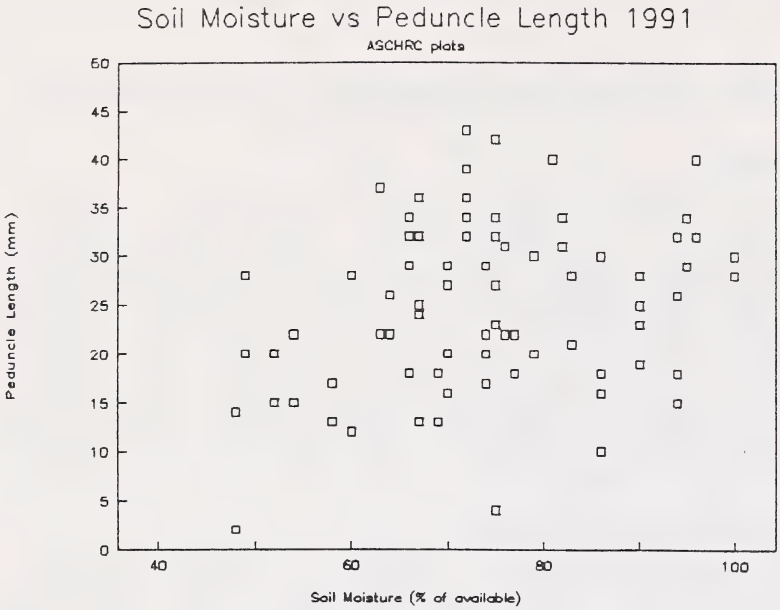


Figure 1. Soil Moisture vs Peduncle Length (ASCHRC plots)

Peduncle length did, however, seem to decrease as the season progressed (successive racemes were shorter than previous ones), even on the well-watered plots. A more definitive relationship between peduncle length and soil moisture may result if peduncle length were to be corrected for date, raceme number or other variables.

## Tripping Percentage

The tripping percentage was recorded at a few, selected sites in mid-August which is the traditional cut-off for viable seed in our area. Each raceme was examined for number of florets and subsequent curls (seed pods).

Data was collected for general information only, and will be used as a standard once we turn our attention to this area.

## SUMMARY

This project was initiated by the Irrigated Alfalfa Seed Producers Association of Alberta with the intention of gathering information on alfalfa growth which could be used to schedule irrigation and increase yields. Five plant parameters were measured in an attempt to define an indicator which would relate directly to soil moisture status.

There is no single plant measurement taken in 1991 which demonstrated a strong correlation with soil moisture. Combining parameters and correcting for date or other external factors may be the only means of eliciting a measurable crop response to soil moisture stress. Data collection will continue for 1992.

# THE DEVELOPMENT AND APPLICATION OF AUTOMATED SOIL SALINITY MAPPING

C. Livergood, B. Read, and D. Wentz[1]

## INTRODUCTION

In recent years, advancements have been made in the measurement of the bulk electrical conductivity of surface soils. One such advancement is the development of an EM38 electromagnetic conductivity meter by Geonics Limited of Mississauga, Ontario. The EM38 lends itself to be linked to a data processor, allowing large tracts of land to be investigated in relatively short periods of time, thereby increasing the efficiency and effectiveness of soil salinity mapping.

The Conservation and Development Branch of Alberta Agriculture embarked on a program to develop a system of rapidly acquiring field data and transfering this information to a site specific location in the field. The results of the program would identify field conductivity levels, providing criteria for the implementation of reclamation controls.

## METHODS

### Principles of Operation

The EM38 is a electrical conductivity meter designed to rapidly measure field conductivity without requiring soil contact (Figure 1). The unit is comprised of a self contained dipole transmitter located at one end and a self contained dipole receiver located at the other end separated by an inter-coil spacing of 1.0 metres. When energized, the transmitter produces an electromagnetic field that induces current flow in the soil. The magnitude of the current flow is proportional to the bulk electrical conductivity of the soil through which the current passes. This current produces a secondary electromagnetic field which is sensed by the receiver and converted to an output voltage. This output voltage is linerally related to the bulk soil electrical conductivity.

Because the EM38 produces an electrical voltage or analog signal and the computer to which it is connected produces a digital reading, a convertor developed by Pulson Engineering was incorporated into the system. This was important to accurately reproduce the EM38 signal for processing.

The EM38 can operate in either a vertical of horizontal position. Vertical EM readings give an indication of salinity levels either evenly distributed throughout a 150 cm soil profile or concentrated in the lower 90 cm. Horizontal readings indicate salinity in the upper 90 cm

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of the profile. The use of either horizontal or vertical readings has implications on cropping recommendations due to variations in crop rooting depth and crop salt tolerance.

Figure 1. EM38 operation

## System Components

The data collection system, which is linked to the EM38, consists of a lap-top computer which stores and processes data. A magnetic switch attached to a metering wheel opens and closes at specified intervals and signals the computer which of the data values incoming from the EM38 to accept and record. The EM38 itself is mounted at a constant height on a sled constructed of PVC tubing. This material was chosen because of its non-conductive nature and as such it would not influence the EC readings. The sled is pulled through the field behind a 4x4 all terrain cycle along predetermined grid lines at a speed of about 5 kmph (Figure 2).

The spacing of the grid lines is dependant on the size of the field being mapped and the desired detail of the map being produced. Naturally, the closer the grid lines are, the greater the volume of data which will be collected. The volume of data which is available means less interpolation by the computer when plotting EC isometric lines on a map.

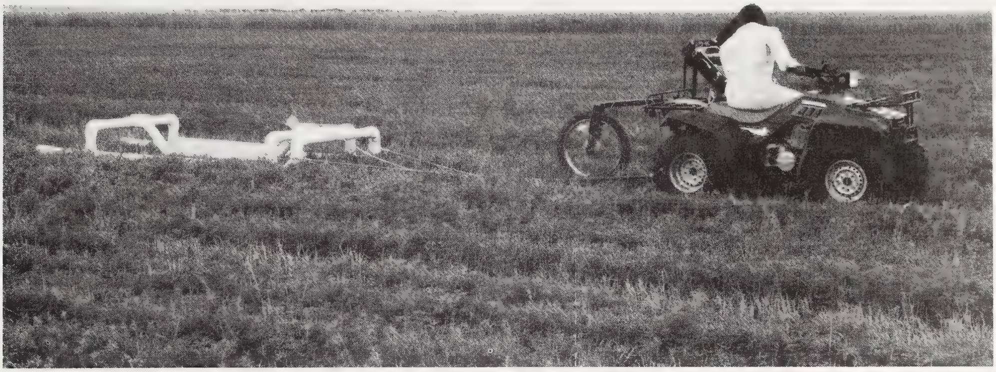

Figure 2. System components.

### Software Development

The software of the system is an adapted version of a program which gathers and compiles information generated by the EM38. The original program, developed by C. Travis of PFRA, incorporated the use of directional and starting coordinates to orientate the computer as to its field position. With this program, coordinates had to be entered manually and correctly to ensure accurate data collection. It was important, therefore, to develop a program which would streamline this process. In doing so, it was expected that the following would be accomplished: operator error would be eliminated; advances in computer technology and programming could be employed to maintain quality control; a fast and economical mapping system could be implemented which could be easily operated by someone with limited computer knowledge.

Another feature incorporated during the development of the system was to allow for the operator to observe the data as it is being recorded in the field. This is important because the operator is able to visually see changes in the soil conductivity and flag specific locations for future soil sampling.

The next step in the software development was to provide for the input of parameters which would allow the computer to convert raw readings into a standard form which could be more easily interpreted. Parameters such as soil temperature, moisture and texture all affect soil electrical conductivity and these factors are important in the accurate calibration of the instrument. However, it has been found that wide variations in soil moisture and texture throughout a field reduce the accuracy of the calibration and in many instances readings are corrected for temperature only. These readings provide an indication of relative salinity changes within a field rather than absolute values. In cases where the definition of recharge-discharge areas is the primary objective, raw readings suffice.

In investigations where more specific calibration of the instrument is required, the design of the system allows for this. The number of wheel rotations per reading tells the computer when to take a reading. Since the readings are started at a known point and the circumference of the wheel is also known, any point in the field can be located and soil sampled and the EM values can then be related to a saturated paste value for calibration purposes.

<u>Map Production</u>

The field data is collected and stored on disk in a three column (x,y,z) format. The file in which this information is contained is imported into a software package with contouring capabilities. The particular software used by the C&D Branch is "Surfer". With this package, detailed two dimensional contour maps and three dimensional diagrams are produced which provide representations of soil salinity for the specific area under investigation (Figures 3 and 4).

The new system currently requires that salinity maps must be produced in an office setting, but with portable computing components becoming available, it may soon be possible to generate salinity maps in the field, allowing the investigator to make cropping and reclamation recommendations to the farmer on the spot.

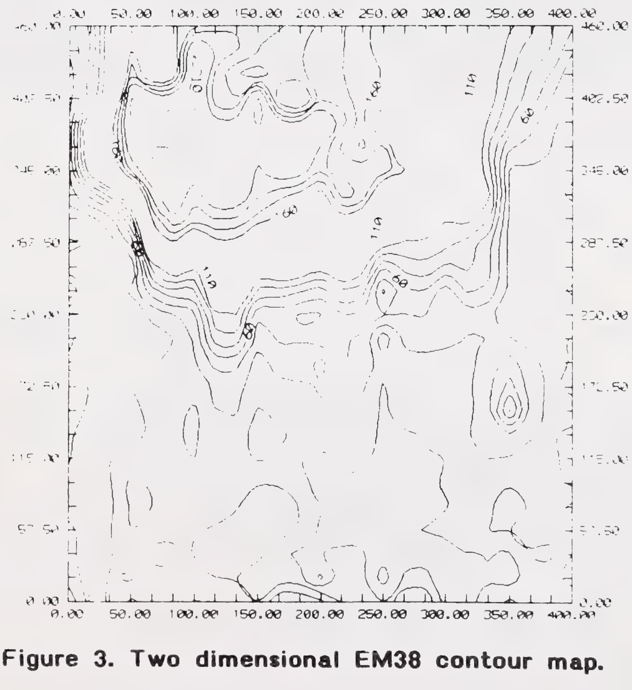


**Figure 3. Two dimensional EM38 contour map.**

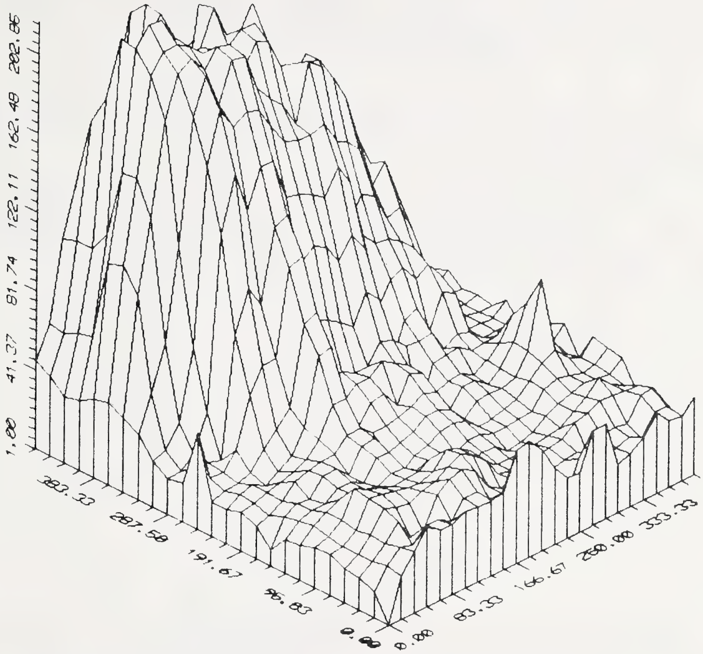


**Figure 4. Three dimensional conductivity diagram**

## CONCLUSION

The detailed determination of soil salinity on a field scale was once a labor intensive and time consuming process involving physical sampling (drilling), laboratory analysis and the manual preparation of maps. The process of salinity mapping has evolved into an electronic system which can now map a quarter section of land in about four hours as compared to three or more days when performed manually.

Work is also underway to develop a method of rapidly mapping surface topography in conjunction with salinity variations so as to relate soil salinity to surface expression.

Alberta Agriculture has taken a lead role in the development and application of soil salinity mapping. Research is on-going in this field and is continuing to advance this technology further.

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# TIMING BEE EMERGENCE TO COINCIDE WITH OPTIMUM ALFALFA PLANT FLOWERING STAGE

G. Snaith and D. McKenzie[1]

## INTRODUCTION

Alfalfa must be cross-pollinated to obtain top yields. For this purpose, the leaf-cutter bee is used. This bee requires a 21 day incubation period for the overwintered pre-pupae to hatch. The timing of the hatch must ensure that there will be an adequate supply of alfalfa flowers or else the bees will leave the field in search of food. On the other hand, the grower would like to take advantage of the first alfalfa flowers, which are known to produce the best seeds.

Traditionally, growers have used either a calendar date or waited until they observed the first flower in the field as a method of determining when to start the incubation process. This project was initiated in an attempt to find a better method for making this determination.

## METHODS

Once a week, a technician picked 50 stems at random from each of 20 fields. These stems were sorted into 4 groups: no buds, bud swell (the bud can be felt by gently squeezing the plant tip between thumb and forefinger), buds visible (the bud can be readily seen), and flowers visible (color can be readily detected). The procedure was continued until the field was beyond the 50% bloom stage (more than 1/2 the stems had flowers visible). Adequate timing for incubation was determined by observing the optimum bee introduction plant stage of development (40-50% bloom) and subtracting 21 days (the time required for pupation).

## RESULTS AND DISCUSSION

It became apparent that total degree days above 5 degrees Celsius (DD), as supplied by Alberta Agriculture's Conservation and Development Branch, has a large influence on alfalfa development. May 1990 (198 DD) was very close to normal, whereas May 1991 (215 DD) was above the 30 year average (195 DD). This resulted in an advance of approximately 10 days in crop development (figure 1).

A strong relationship between bud swell and flowers visible also appeared to exist whereby 50% flowers visible occurred approximately 26 days after 50% bud swell in both 1990 and 1991. Bud swell could therefore be used as an indicator for commencing incubation in order to coordinate hatching date with stage of flowering.

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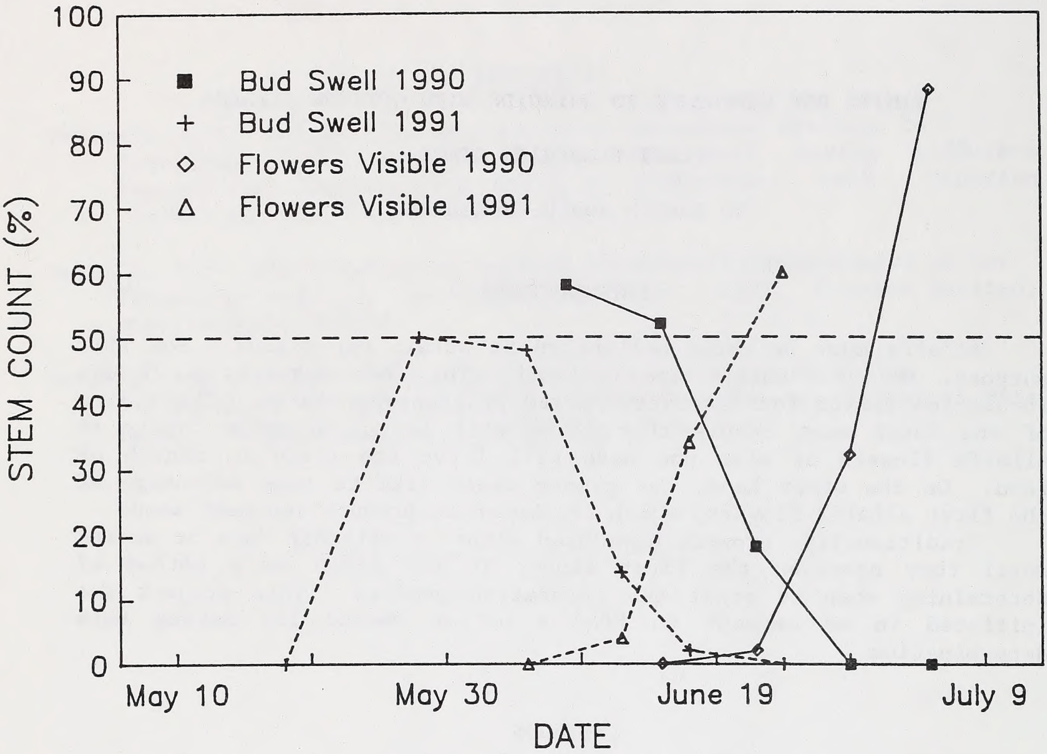


Figure 1: Annual variation in alfalfa raceme development for 1990 and 1991

SUMMARY

It may be possible to use this data to accurately predict incubation date. A further possibility is to use weather data supplied by Conservation and Development Branch to obtain a relationship between crop development stage and cumulative degree days. However, problems exist in obtaining this data on a daily or weekly basis. The degree day calculation would have to be made manually from data received from the Alberta Special Crops and Horticultural Research Centre's weather station.

The project will continue for at least one more year, in order to obtain more empirical data on crop development and degree days. As it stands, it will be used in 1992 to predict incubation commencement dates, with the accuracy to be assessed after subsequent bee introduction.